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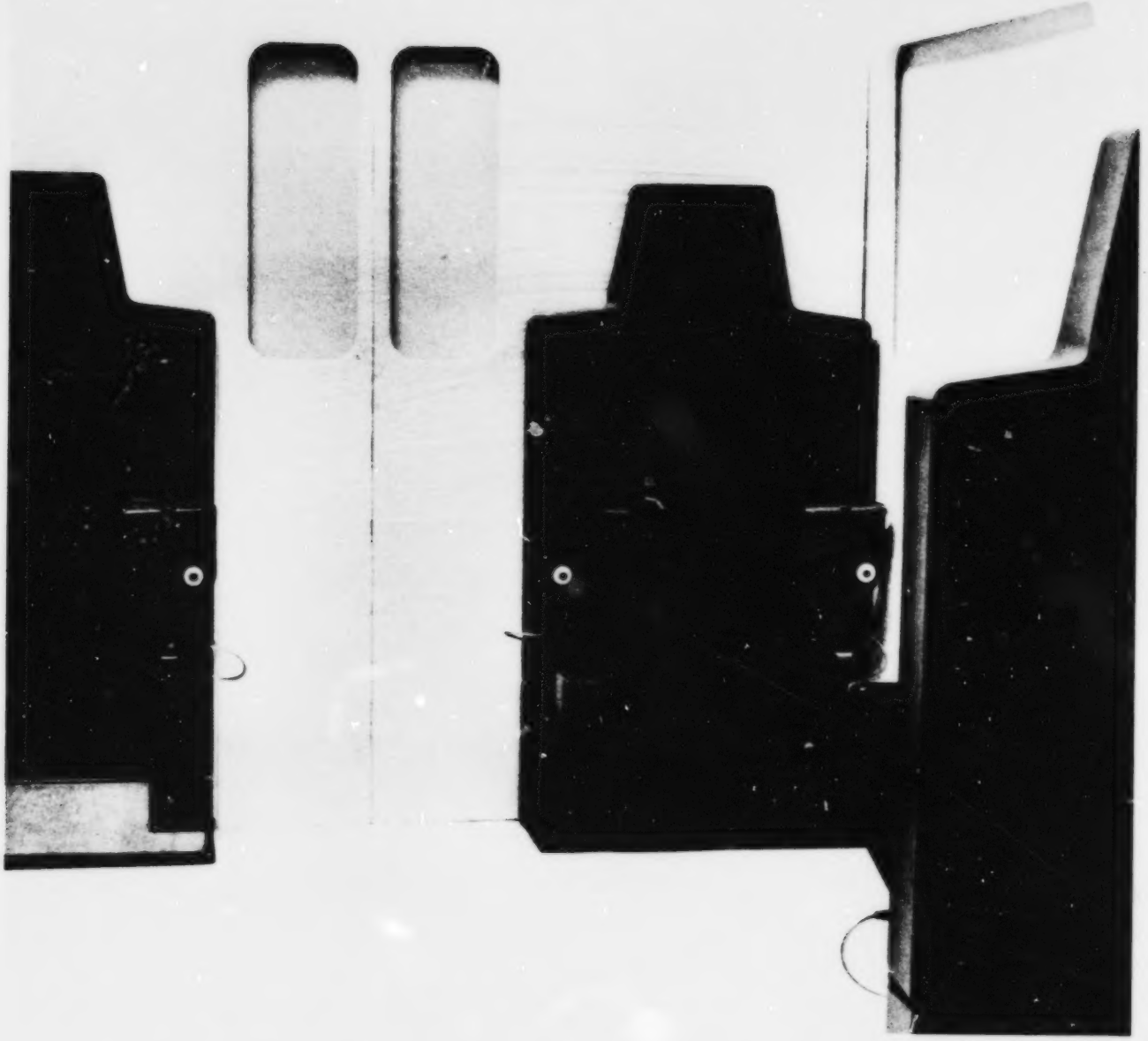

Multimodal Wheelchair Securement Passenger Restraint– Prototype Development

for Transportation Development Centre
Transport Canada

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by Douglas Ball Inc.

May 1981

TP 3057E

MULTIMODAL WHEELCHAIR SECUREMENT/PASSENGER RESTRAINT

PROTOTYPE DEVELOPMENT

by

Uwe Rutenberg
Douglas Ball Inc.
Sainte-Anne-de-Bellevue, Quebec

For

Transportation Development Centre
Transport Canada

May 1981

Transport Canada/Transports Canada
Library and Information Centre/
Centre de Documentation
Ottawa, Canada K1A 0N5 GSLA

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REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP 3057E	4074	

4. Title and Subtitle	5. Report Date
MULTIMODAL WHEELCHAIR SECUREMENT/PASSENGER RESTRAINT - Prototype Development	May 1981
	6. Performing Organization Report No.

7. Author(s)	8. Transport Canada File No
Uwe Rutenberg	D1450-103-12-4

9. Performing Organization Name and Address	10. DSS File No.
Les Designers Douglas Ball Inc. 88 Ste-Anne Street Ste-Anne-de-Bellevue, Quebec H9X 1L8	09SD.T8200-9-9536
	11. DSS or Transport Canada Contract No.
	OSD79-00108

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Transportation Development Centre (TDC) 1000 Sherbrooke Street West P.O. Box 549, Pl. de l'aviation Montreal, Quebec H3A 2R3	Final - Feb. '80 - May'81
	14. Sponsoring Agency Code
	TDC 4074

15. Supplementary Notes	16. TDC Project Officer
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17. Abstract

This report outlines the development and testing of a prototype wheelchair securement/passenger restraint system. The modular system consists of arms, which engage the wheels to secure the wheelchair against the back structure of the system, and a three point belt system to restrain the wheelchair user. The system is applicable to multimodal use with the exception of the air mode. The report describes the construction of the prototypes, laboratory strength testing and in-service operational evaluation.

18. Key Words	19. Distribution Statement
Wheelchair securement, tiedown, passenger restraint, physically handicapped.	Limited number of copies available from Sponsoring Agency.

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
nil	nil	96	nil

FORMULE DE DOCUMENTATION POUR RAPPORT

1. N° du rapport Transports Canada	2. N° de l'étude — CDT	3 N° de catalogue du destinataire
TP 3057E	4074	

4 Titre et sous-titre	5. Date du rapport
MULTIMODAL WHEELCHAIR SECUREMENT/PASSENGER RESTRAINT - Prototype Development	mai 1981
	6. N° du rapport de l'organisme exécutant

7 Auteur(s)	8 N° de dossier Transports Canada
Uwe Rutenberg	DI450-103-12-4

9. Nom et adresse de l'organisme exécutant	10 N° de dossier — ASC
Les Designers Douglas Ball Inc. 88 Ste-Anne Street Ste-Anne-de-Bellevue, Quebec H9X 1L8	09SD.T8200-9-9536
	11 N° de contrat — ASC ou Transports Canada OSD79-00108

12. Nom et adresse de l'organisme parrain	13 Genre de rapport et période visée
Centre de développement des transports (CDT) 1000 rue Sherbrooke, ouest C.P. 549, pl. de l'aviation Montréal, Québec H3A 2R3	Final - fév. '80 - mai '81
	14. Code de l'organisme parrain TDC 4074

15. Remarques additionnelles	16 Agent de projet — CDT
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17 Résumé

Rapport sur les travaux de développement et d'essai du prototype d'un système modulaire d'ancrage de fauteuils roulants, comportant des bras qui immobilisent les roues motrices du fauteuil et le retiennent contre un support dorsal, et un ancrage en trois points immobilisant le voyageur handicapé. Ce système convient à tous les modes de transport sauf aux transports aériens. Ce rapport décrit en outre la construction des prototypes, les essais de résistance exécutés en laboratoire et l'évaluation opérationnelle éprouvée en service.

18. Mots-clés	19. Diffusion
Ancrage de fauteuils roulants, immobilisation, transports de personnes à mobilité réduite.	Le CDT dispose d'un nombre limité d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
aucune	aucune	96	gratuit

SUMMARY

This report presents the findings of the second phase of a program initiated by the Transportation Development Centre of Transport Canada to develop a wheelchair securement and passenger restraint system offering safe transportation to the handicapped traveller on various transportation modes. In the first phase a concept was defined by Douglas Ball Inc. for a modular system with potential for achieving such a goal. The system would accommodate wheelchairs from 45 cm to 72 cm (18 to 28 inches) in width with wheel diameters between 50 cm and 66 cm (20 to 26 inches).

The specific objective of the current work was to develop a wheelchair securement system for multimodal application. Four prototype units were to be constructed, one to be static tested for strength and three to be used for an in-service performance evaluation.

In order to achieve this objective, Douglas Ball Inc. upgraded the concept drawings prepared in phase I to be suitable for prototype construction, fabricated four prototypes and developed a testing methodology which was followed by laboratory tests at TES Limited, Ottawa. An in-service evaluation was carried out, based on the performance of the two prototypes which were installed in a vehicle operated by M & O Bus Lines (Handicab) Limited, Ottawa.

No major defect in the concept was revealed from the laboratory tests and in-service operational service. The unit was well received by the potential users whose suggestions aimed at making the unit more versatile (e.g. accommodate more types of electric wheelchairs) and making it more convenient for the driver to deploy restraint arms and belts.

The results of the project indicate that a significant step has been taken toward providing the handicapped traveller with the same level of safety now enjoyed by other travellers.

RESUME

Rapport sur les résultats des travaux de la Phase II du programme lancé par le Centre de développement des transports, Transports Canada, et visant la mise au point d'un système d'ancrage de fauteuils roulants, grâce auxquels les personnes à mobilité réduite pourront emprunter en toute sécurité divers modes de transport. Au cours de la phase I du projet, Douglas Ball Inc. avait défini le concept d'un système modulaire pouvant s'appliquer à des fauteuils roulants ayant de 45 à 72 cm (18 à 28 pouces) de largeur et de 50 à 66 cm (20 à 26 pouces) de diamètre de roue.

La Phase II, visant le développement d'un système multimodal, prévoyait la construction de quatre prototypes d'essai, un destiné aux essais de résistance statique en laboratoire et les trois autres à l'évaluation du fonctionnement en service.

Répondant à cet objectif, Douglas Ball Inc. a repris le concept qu'elle avait esquissé au cours de la Phase I et l'a concrétisé sous forme de prototype dont quatre ont été construits. La firme a élaboré une méthodologie d'épreuves suivie d'essais aux laboratoires de TES Limited d'Ottawa. Elle s'est également occupée de l'organisation et de la mise en exécution de l'évaluation du fonctionnement, en service, notamment en faisant installer deux systèmes d'ancrage dans un autobus appartenant à la M & O Bus Lines Limited d'Ottawa.

Ni les essais de laboratoire ni l'évaluation en service n'ont relevé de défauts pouvant être considérés comme sérieux. Au contraire, le module a été bien accueilli par les futurs utilisateurs qui ont présenté des suggestions visant à le rendre plus souple, c'est-à-dire apte à recevoir certains autres types de fauteuils électriques, et plus commode pour l'usager dans la méthode utilisée de serrer les sangles et faire sortir les bras de l'immobilisation.

Les résultats obtenus démontrent qu'une étape importante a été franchie vers l'objectif de permettre aux personnes handicapées de se déplacer dans les mêmes conditions de sécurité que les autres catégories de voyageurs.

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1. INTRODUCTION

1.1 General

Previous work commissioned by the Transportation Development Centre (TDC) of Transport Canada relating to the transportation of the handicapped resulted in the development, by Douglas Ball Inc., of a tie-down system for wheelchairs for use in rail passenger cars (1). Building on that experience, Douglas Ball Inc. developed, under contract to TDC, a concept of a wheelchair securement/passenger restraint system to enhance the safe transportation of all wheelchair travellers and be suitable for several transportation modes. Although specific consideration was given to vans, the concept has potential for use in transit buses, intercity buses, ferries and trains. A similar light-weight concept might be used for aircrafts.

The multimodal concept for the wheelchair securement/passenger restraint system consists of four modular elements: 1) a wedgetrack; 2) a bulkhead; 3) a shoulder rest incorporating a shoulder belt, back and head support; and 4) a special seat suitable for use by ambulatory passengers (2). These elements would be used in various combinations to meet the needs of different applications. The proposed concept clearly responded to the need for a multimodal restraint system for wheelchairs that would offer the wheelchair traveller the element of safety currently available to other travellers.

This report describes the development of the wheelchair securement/passenger restraint system after the concept definition phase through the first prototype phase. This phase saw the fabrication of one prototype unit for laboratory testing and three units for in-service performance evaluation. Supporting design drawings and associated specifications were also developed during this phase.

1.2 Objectives

The overall objective of this project was to improve the accessibility and safety of transportation systems for the physically disabled passengers. The specific objective was to develop a wheelchair securement for multimodal application offering the same degree of protection as car passengers. These units were to be static tested for strength and used for an in-service performance evaluation in a bus service dedicated to transport the handicapped. The findings of these activities were to be analyzed. Documentation would include a specification and tender package.

2. DESIGN CONCEPT FOR WHEELCHAIR RESTRAINT SYSTEM

2.1 General

With the ability to travel being a basic requirement for self-sufficiency, persons confined to wheelchairs are often denied their independence due to travel barriers rather than their particular handicap. To facilitate the ability to travel, the wheelchair securement concept was developed. It offers the wheelchair traveller the degree of safety available to the rest of the travellers. The concept also offers a solution to transportation service companies who could not always be expected to hold dedicated revenue space for wheelchair travellers. The modular design permits the seating of ambulatory passengers as well as the accommodation of those in wheelchairs.

2.2 Innovative Design Features

The wheelchair securement consists of four modular elements to provide varying degrees of security ranging from simple securement of the wheelchair to a full passenger safety unit.

In its simplest form the system secures the wheelchair by restraining arms that secure over each of the large driving wheels of the chair. These arms pull the wheelchair rearward against the wedgetrack and downward against the vehicle floor (Figure 1). The arms slide laterally to accommodate wheelchairs ranging from 45 to 72 cm (18 to 28 inches) in width. The arms telescope to accept wheel diameters between 50 and 66 cm (20 and 26 inches).

Additional modules (i.e. bulkhead, backrest and attachable seat) can be added to meet different transportation needs and provide various levels of security (Figures 2 and 3). The attachable seat permits operators to use the space when a wheelchair passenger is not travelling. The pivoting arms of the seat module facilitate access to and egress from the seat.

The lap and shoulder belts are arranged to permit the lap belt to be fed under the armrests of the wheelchair for proper deployment over the hips of the passenger. The cushioned head and back supports are adjustable so that they can be positioned as close as possible to the passenger's back.

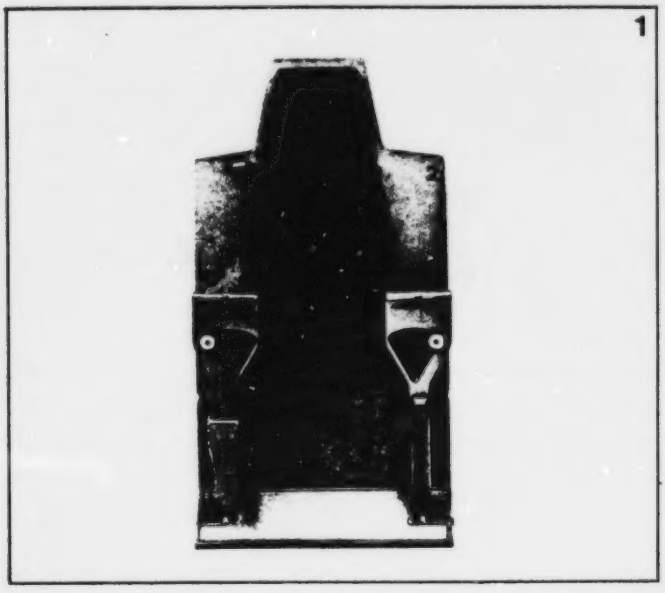
2.3 Installation

The wheelchair securement is installed in the vehicle via attachment points to be provided on the floor and on a wall of the vehicle (Figure 4). If the wheelchair securement is to be in a freestanding position, attachment points must be provided on the floor and ceiling of the vehicle. In these cases an extra support bracket extending from the top of the wheelchair securement to the ceiling must be used. It has been established that the most satisfactory orientation of the unit is that which permits the passenger to face forwards or backwards (3).

Sideways installations are less acceptable from a safety point of view.

2.4 Application

The wheelchair securement could be used in any transportation service that requires the securement of wheelchairs and the protection of passengers. It is, however, designed primarily for use in systems where the transportation operator is responsible for operating the wheelchair securement; it would not be suitable in its present form for use in systems where entry and exit times are critical to maintaining schedules.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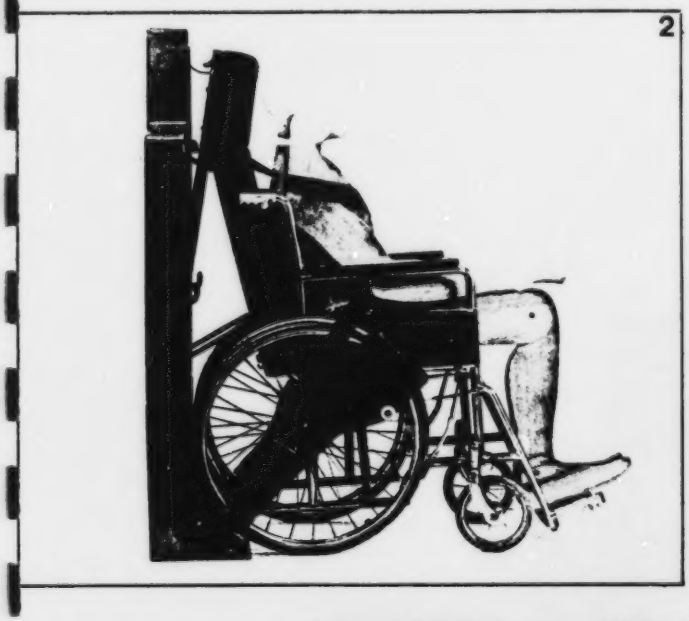
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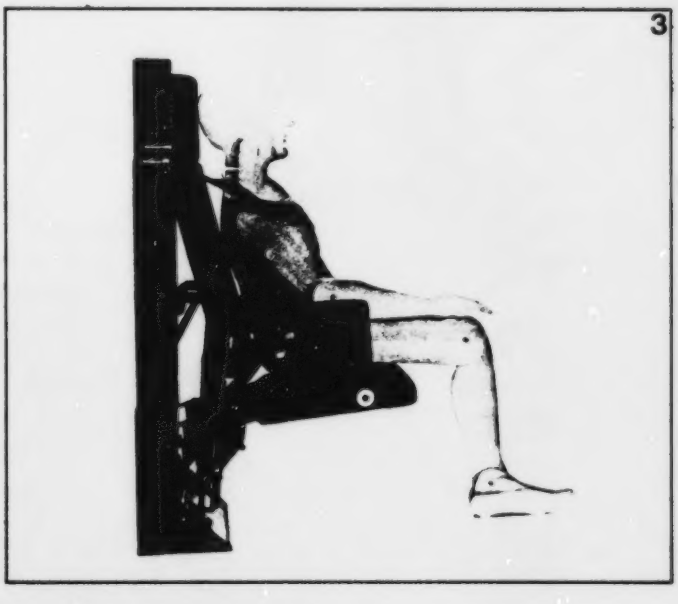
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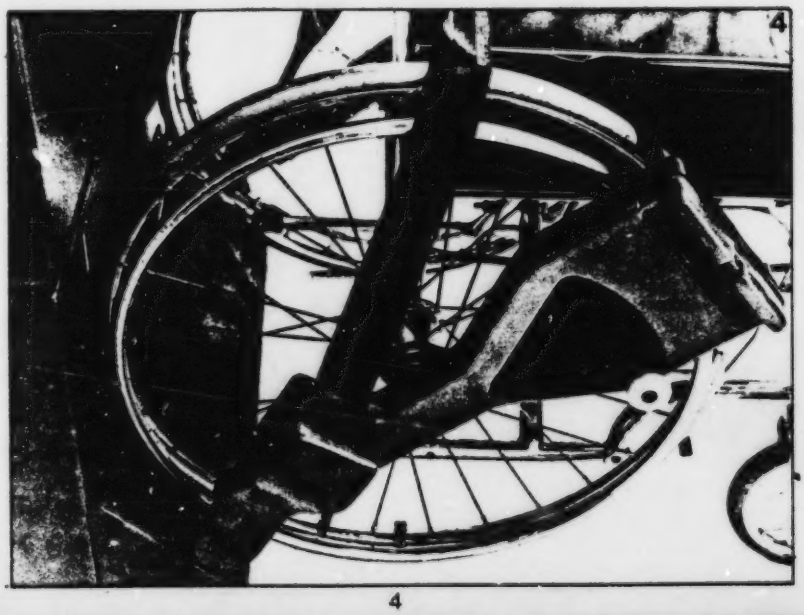
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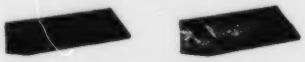

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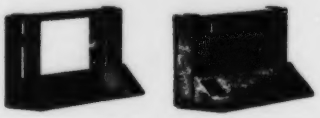

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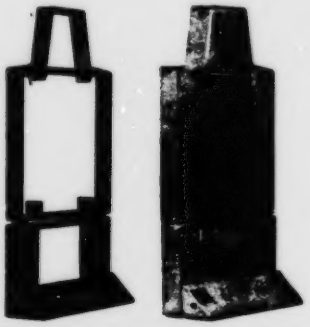

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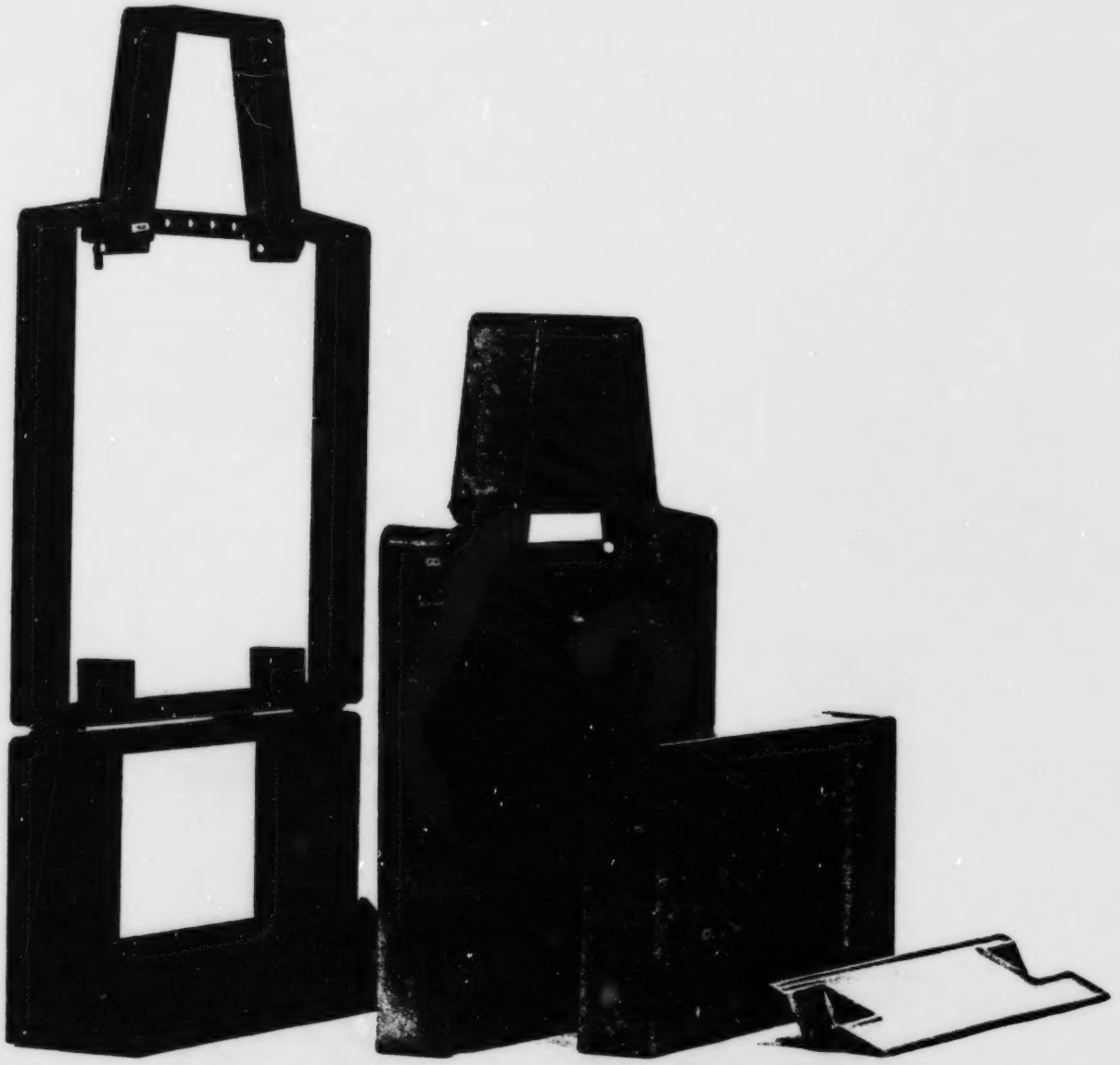

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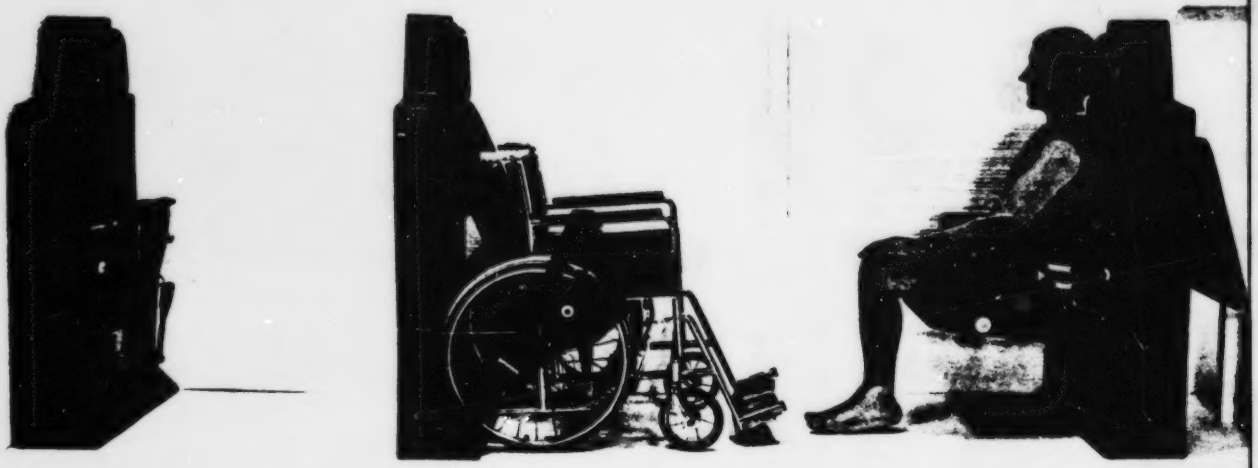

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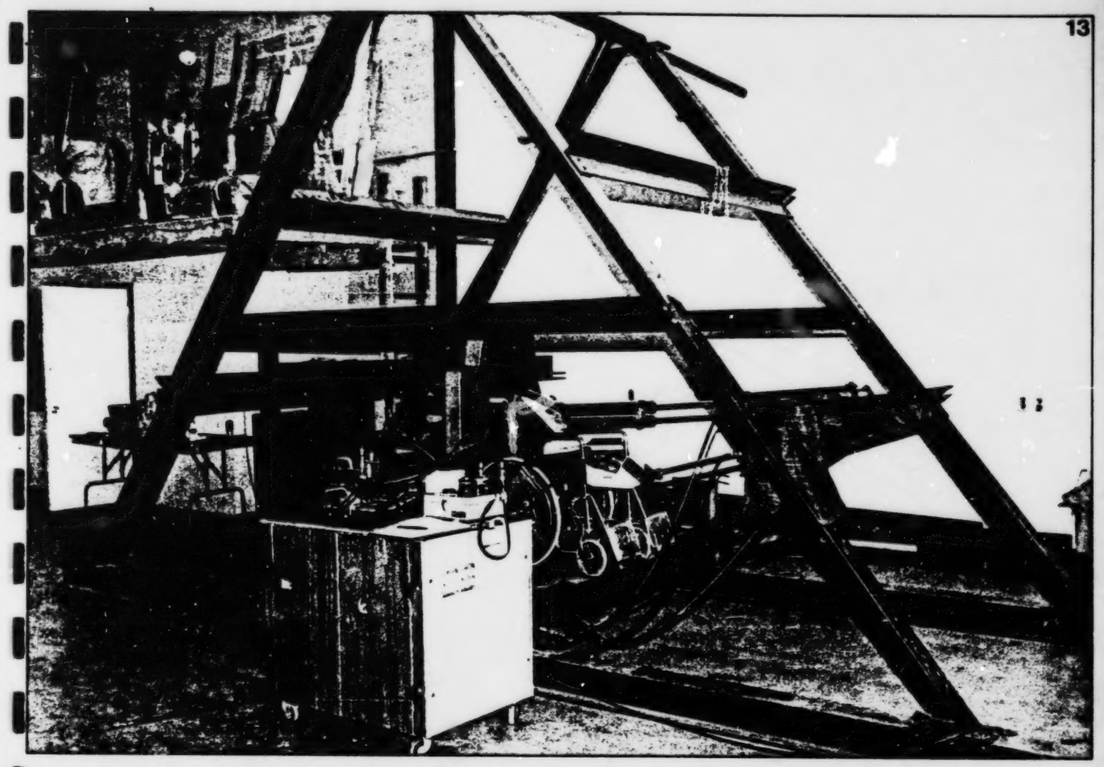

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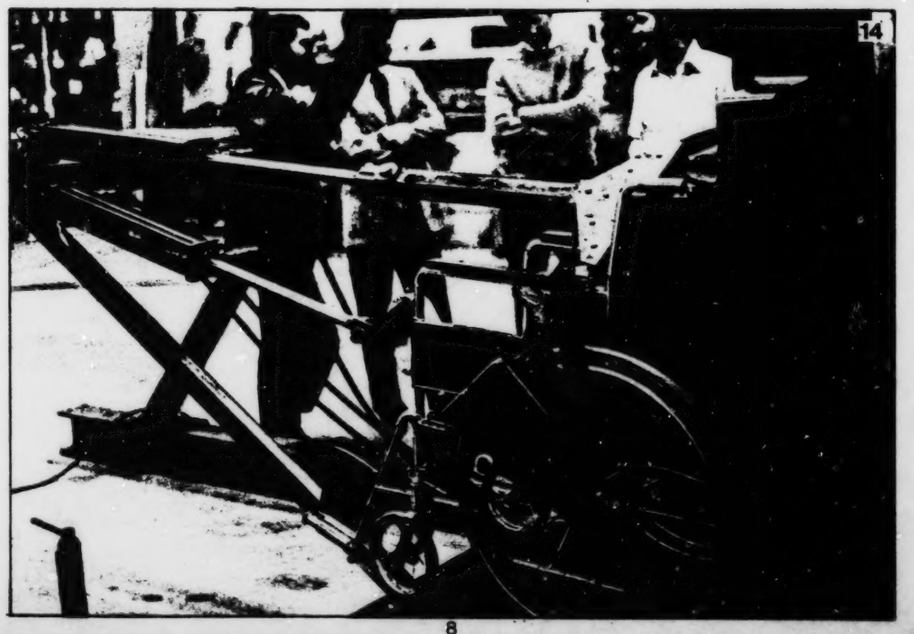

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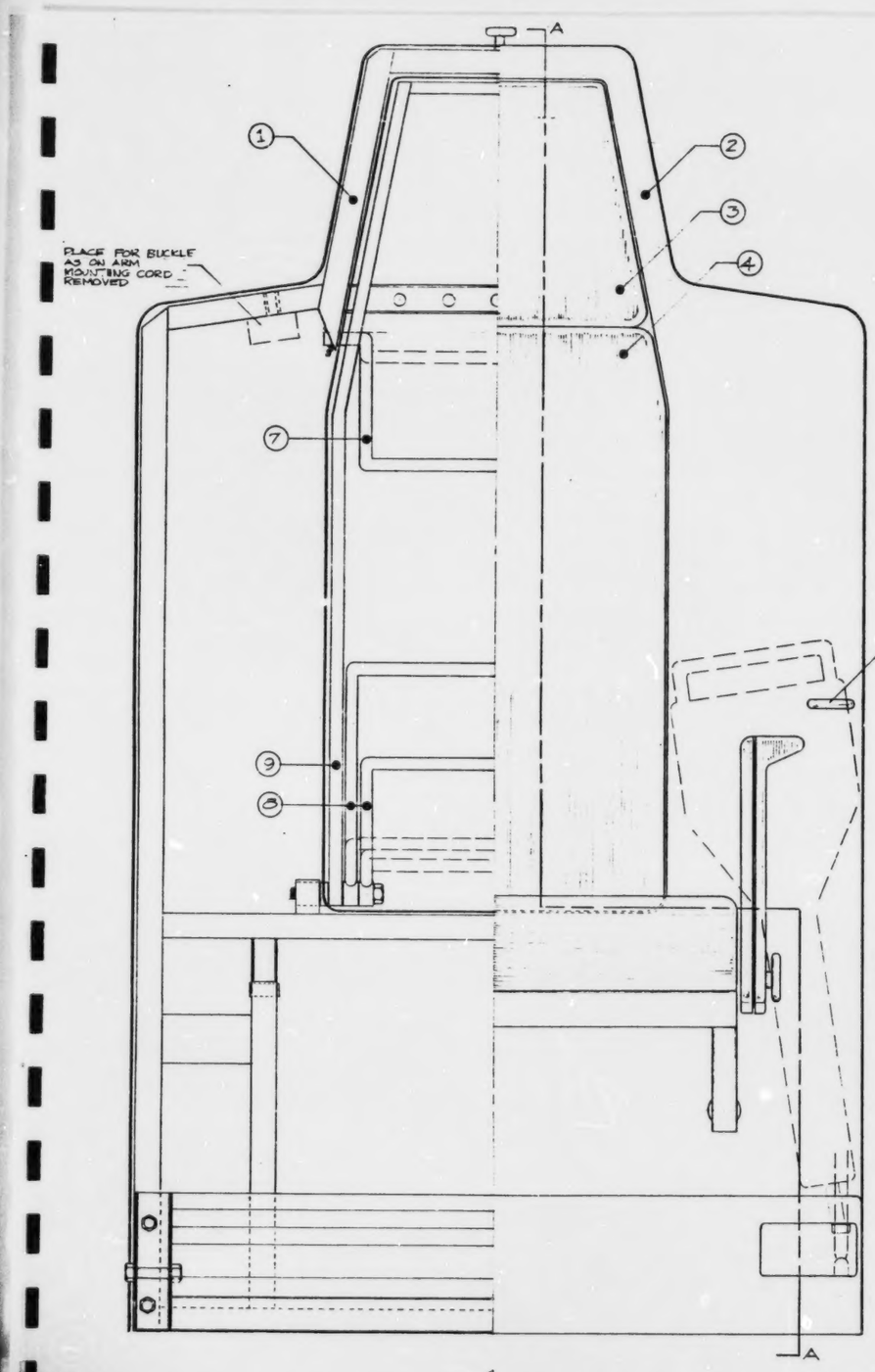

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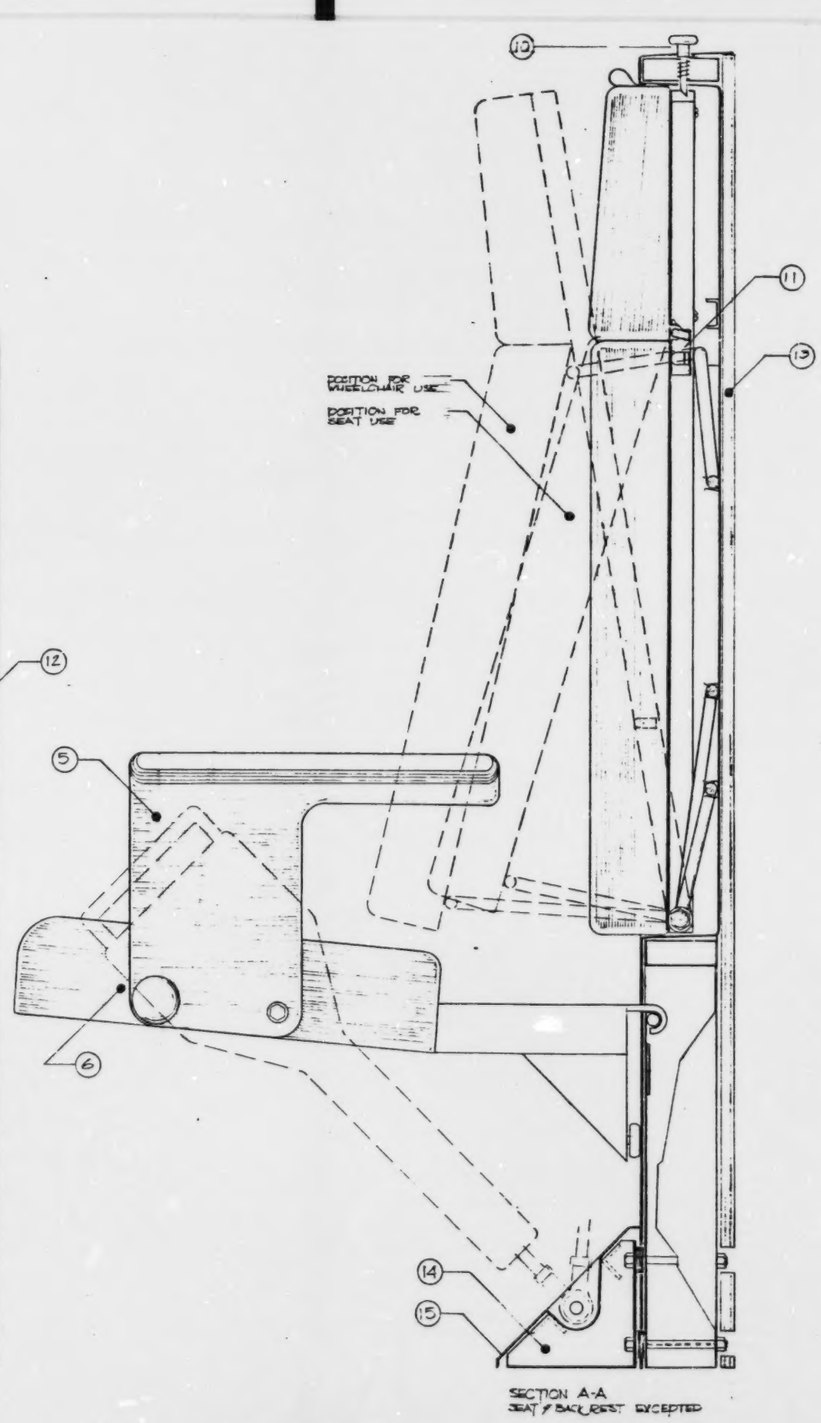

SECTION A-A
SEAT & BACKREST EXCEPTED

1 FRAME
2 PLASTIC HOUSING FRAME
3 HEAD REST
4 BACK REST
5 ARM REST
6 SEAT
7 BACK REST SUPPORT - UPPER
8 BACK REST SUPPORT - LOWER
9 BACK REST PIVOT ARM
10 BACK REST LATCH
11 BACK REST SUPPORT LATCH
12 RESTRAINT ARM STORAGE HOOK
13 BACK COVER
14 RESTRAINT ARM ATTACHMENT WEDGE
15 WEDGE COVER

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Project/Projet
WHEELCHAIR RESTRAINT SYSTEM

Designation/Name of drawing
ASSEMBLY BACK REST DRWG.

Design par/Designed by
U. RUTENBERG L. GOLDIK

Dessiné par/Drawn by
LG

Echelle/Scale
3/8" - 1"

Date/Date
3-3-81

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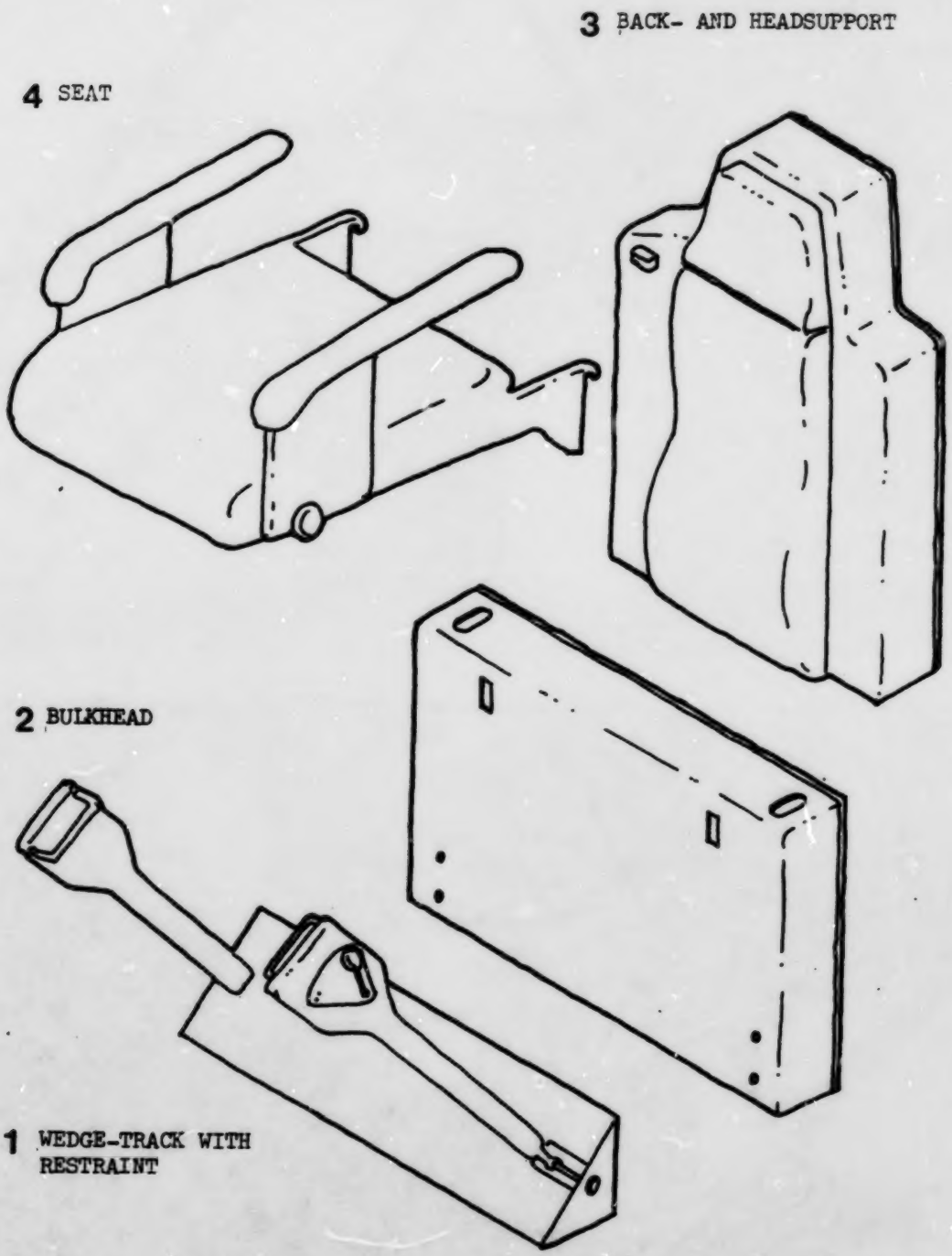

Figure 15

Exploded View of the Restraint System

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3. MAJOR DEVELOPMENT ACTIVITIES

3.1 General

To ensure that the prototype development of the wheelchair securement would meet the objectives of Transport Canada, a schedule of milestone activities was identified. These activities permitted Douglas Ball Inc. to make efficient use of the testing facilities available and to obtain relevant data from a broad segment of potential users.

The major milestone activities were:

- Upgrading design drawings and establishing test criteria
- Manufacture of prototypes
- Static laboratory testing
- In-service performance evaluation

The work was scheduled to be carried out in the twelve month period between February 1980 and February 1981.

3.2 Upgrading Design Drawings and Establishing Test Criteria

Design requirements for the travelling wheelchair itself were specified in the concept definition phase of the program. A wooden mock-up was built to demonstrate the concept and the overall dimensions for the unit were established. The upgrading of existing drawings for building the prototypes concentrated primarily on incorporating the mechanical design necessary for the system to withstand the forces expected, provide the comfort and aesthetic values required by the passenger and the ease of operation required by the transportation system operators. Because the wheelchair securement probably will not ever be produced in large quantities, consideration was also given to availability of materials and to using fabrication techniques within the capability of most machine shops (Appendix A).

Areas of major concern in the design were:

- The restraint arm mechanism
- The securing points for the belts
- Strength and safety considerations

Test criterion for static loading conditions was:

To restrain an occupant independently of a device used to secure a wheelchair in the event of a crash. The Canadian Motor Vehicle Safety Standards (CMVSS) regulates the design and performance characteristics of occupant restraint systems for anchorage strength, belt webbing strength and anchorage location (Section 207, 208, 209, 210).

Test methods and procedures are shown in Appendix B.

3.2.1 Restraint Arm Mechanism

One of the major differences between the tie-down mechanism developed for rail car service and the wheelchair securement is the purpose for which the restraint arm mechanisms were designed. The tie-down for railway application was only for securement of the wheelchair, while the other had to respond to safety requirements in a collision situation. The forces required to restrain a wheelchair in a train were far less than those which would occur during an accident situation in a smaller vehicle. The friction-hold device used for the rail unit was discarded and a positive lock, simple but strong, using a rack and pinion mechanism was designed.

The result was a set of restraint arms that can each slide horizontally approximately 10 cm (4 inches) to accommodate wheelchair widths from 45 to 72 cm (18 to 28 inches). The arms also swing sideways and up to 90° vertically by means of a revolving joint (Figure 4). Inside each arm there is a telescoping movement incorporating a rack and modified pinion to adapt to wheel diameters between 50 and 66 cm (20 and 26 inches). When the arm hook is placed over the tire, a lever is pushed to turn the pinion which engages on the rack giving a positive lock.

The lever on the outside of the arm can be locked in both the up or "open" position (for free movement of the telescoping movement) and the down or "locked" position (for securing the wheelchair). The arrangement of the rack and pinion is such that when the lever reaches its down or "locked" position the tire of the wheelchair has been compressed 6 to 12 mm ($\frac{1}{4}$ to $\frac{1}{2}$ an inch) under each arm hook to ensure that the wheels are positively immobilized without deforming the rim.

The hook is designed in such a way that it clears the handrim to fit between the arm panel and the tire. The hook is covered by a rubber hose to protect both the user and the wheelchair. When the arm is not in use, it is parked in a vertical position, secured against the backrest (Figure 1).

3.2.2 Securing Points for the Belt System

The location of the belt system securing points was established according to human factor sources (4). The wooden mock-up of the wheelchair securement had used lap belt securing points on the bulkhead module. When the belt angles resulting from these points were investigated, they were found to be unsuitable. Two anchor points of the belts were then moved to the anchor points of the restraint arms so that the belt would pass over the hips of the passenger.

One arm has a modified reel mechanism which allows the belt to pull out by pressing a small lever. This is not an inertia belt type system because such a system allows movement and gives support only when a jerk-like movement occurs. Very often, physically disabled passengers need extra body support even in a normal riding situation and the inertia system could not provide this.

Because many wheelchairs have fixed arm panels, the belt system also had to permit the lap belt to feed underneath the armrests. The third anchor point, used for the shoulder belt, is on the backrest module.

3.2.3 Strength and Safety Considerations

The location and holding power of the anchor points for the installed wheelchair securement had to be established. Calculations to determine the forces acting on the wheelchair securement in a collision situation were determined largely by extrapolation of safety standards as they apply to the protection of passengers in passenger cars, since few such standards exist for vans. This approach was aimed at providing the wheelchair passenger with the same degree of safe transportation available to other vehicle passengers. To obtain the maximum degree of protection from the wheelchair securement in a collision, the installation of the unit in the vehicle should have the passenger riding backwards. In the event of a crash the passenger's weight would be distributed over the full area of the head and shoulder supports while the wedgetrack and the bulkhead modules would absorb the forces of the wheelchair. If this proves to be impractical and the unit is installed to permit the passenger to face forwards, the three point belt system provides support for the passenger while the restraint arms absorb the forces on the wheelchair. Little or no protection is afforded to a passenger when the unit is installed to have the passenger riding sideways.

All modules, the wedgetrack and restraint arms, bulkhead, backrest and seat have a steel structure as their main strength element. Except for the seat, which is upholstered, each module is protected by vacuum formed shells for safety and aesthetic reasons.

3.3 Manufacture of Prototypes

The manufacture of prototypes in small quantities always presents the problem of purchasing suitable materials and parts. This problem was addressed during the selection of components for the prototypes. Simple fabrication techniques and the availability of materials were given priority consideration in order to keep manufacturing costs to a minimum, to avoid investment in special tooling and to adhere to the project schedule.

Except for a few machined parts in the restraint arms, fabrication methods consist of:

- For metal; cutting, welding, drilling, filing and grinding
- For plastic; vacuum forming, cutting and drilling
- For upholstery; cushion forming

In all areas the plastic and fabrics used are specified to be flame retardant.

Wooden molds were built for vacuum forming the various plastic shells required (Figure 8). The steel structures of the bulkhead and backrest modules are rectangular steel tubes cut and welded. The

correct adjustment for the head and shoulder support on this module is achieved by a U-bracket.

The wedgetrack is fabricated from welded steel plate reinforced by steel triangles. The restraint arms are attached to the wedgetrack by a single horizontal bolt (Figure 5).

Four prototype units were completed. One unit was sent to TES Limited, Ottawa, for laboratory tests and three units were installed in a van operated by M & O Bus Lines (Handicab) Limited, Ottawa, for an in-service performance evaluation.

3.4 Static Laboratory Testing (Appendix B)

TES Limited, Ottawa, as sub-contractor, performed a series of static tests on one of the prototype units (Figures 13 and 14). The specific objectives of the tests were to determine:

- the strength required of the anchorage points in a vehicle to withstand simulated 20-G forces with the wheelchair securement installed.
- the ability of the belt system attachments to withstand 20-G forces on the wheelchair securement with a simulated passenger in a chair or seat.
- the ability of the restraint arms to withstand 20-G forces of the wheelchair.

The tests were conducted according to procedures outlined by Mr. W.T. Gardner, of Transport Canada, Crashworthiness, Automotive Safety, Engineering (Appendix B). The static testing, simulating G-forces and curvature of the human body, gave a good indication of the strength requirements for the anchor points. Failure of components due largely to fabrication and assembly faults prevented adequate achievement of the two objectives.

The results of the tests clearly indicated that the wheelchair securement is conceptually adequate but has several deficiencies in its component parts. Modifications to these components should enable the restraint system to pass all specified loading tests.

3.5 In-Service Performance Evaluation (Appendix C)

During the months of December 1980 and January 1981, three prototypes installed in a newly designed and built van belonging to M & O Bus Lines (Handicab) Limited, Ottawa, underwent an in-service performance evaluation (Figure 12).

M & O Bus Lines (Handicab) Limited was selected for the evaluation because it transports more than 425 disabled persons every day in a short-haul, innercity environment. Although the wheelchair securement was designed for multimodal application, more often than not, a special service transport, such as M & O Bus Lines (Handicab) Limited, is used to meet the needs of the handicapped. Since M & O Bus Lines (Handicab)

Installation of two Wheelchair Restraint Systems in the special van built by M&O Bus Lines, (Handicab) Limited, Ottawa for performance evaluation.

One unit facing driving direction; one backing driving direction.

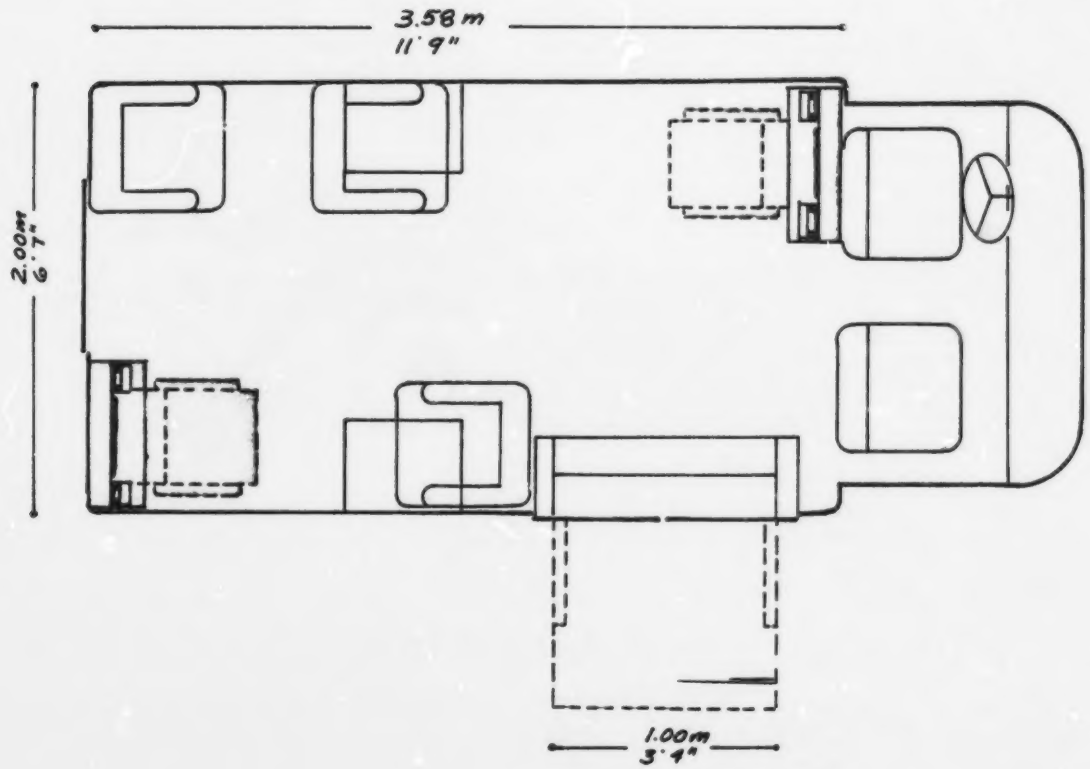


Figure 16

Van Layout for Field Tests

Limited is liable for the safe transportation of its passengers and its drivers must operate lifts to provide entry for wheelchairs, the task of leading the passenger to his seat and being responsible for the appropriate deployment of the safety features (i.e. restraint arms, seat belt and back and head support) of the wheelchair securement is a natural extension of the drivers' duties.

Figures 9 and 10 show several wheelchair securement units deployed inside a mock-up of a van.

The required feedback information was obtained from questionnaires given to wheelchair passengers, ambulatory passengers and drivers. The questionnaires were designed by Dr. Ruth Heron, Consultant Psychologist (Appendix C).

Although only regular passengers were surveyed, the rate of return of the questionnaire was very low. This was probably due to two factors:

- overestimation of the willingness of passengers to participate and
- timing of the test (i.e. Christmas season)

Despite this low rate of return, a considerable amount of information regarding the travellers' opinion of various features of the system was collected.

The drivers, as employees of M & O Bus Lines (Handicab) Limited, responded well although their non-technical orientation resulted in some inappropriate responses.

The detailed results of the evaluation are to be found in Appendix C. In general the response to the wheelchair securement was favourable. However, the van operator reported that there is an increasing use of electric wheelchairs, one of which is wider than the maximum 66 cm (26 inches) allowed for in the design of the wheelchair securement and uses extra wide tires and another that uses wheels much smaller in diameter than the minimum of 50 cm (20 inches) accommodated by the wheelchair securement.

4. RESULTS

The materials and fabrication techniques chosen to build the prototypes were adequate to prove the concept. But, the weight of the arms, due to the steel frames and the lack of precision in assembling some components, caused several problems. In the static testing undertaken by TES Limited, the concept lived up to the expectations of the project. Failures that occurred were largely due to component selection or fabrication. For example:

- The U-bracket that provides adjustment for the head and back support was work hardened during the bending process and subsequently failed.
- The rack and pinion in the restraint arms were improperly assembled and slippage occurred as the result of partial engagement.
- The seat belt, having previously met safety standards, failed due to unknown reasons.

Some movement at the interface of the bulkhead and the backrest module occurred during the test. This total restraint frame is intended to act as a rigid body and even a very small movement causes abnormal loads to be exerted on the anchor points. It proved need for a one-piece rigid frame.

The in-service performance and operator evaluation was on the whole most successful. Comments elicited from the users identified several areas where simple modifications would enhance the usefulness of the wheelchair securement.

- Passengers in electric chairs need wider units capable of accepting small diameter wheels.
- The position of the shoulder belt as it crosses the body is too high for the comfort of most passengers.
- The reel for the seat belt should always be located on the aisle side of the wheelchair securement to be easily accessible to the driver.
- The restraint arms could be made of lighter material.
- The belt was too short to accommodate some wheelchairs.

When ambulatory passengers used the system with the seat installed, it was discovered that the depth of the seat was too short for the comfort of some passengers and for some it was too low.

In general, the users found the unit attractive although somewhat overpowering when several were installed in a small van. The unit is certainly capable of fulfilling a safety need in the transportation of disabled passengers. This was detected in the appreciation of the feeling of security which no other system provides.

5. CONCLUSIONS

The objective of the project to construct and test prototypes of a wheelchair restraint system offering a measure of protection to the passenger was achieved.

a) The prototype construction showed the feasibility of constructing a wheelchair securement using fabrication techniques not tied to economics of large production runs.

b) The laboratory tests provided a first step in the definition of forces exerted on the wheelchair securement and its anchor points in an installation.

c) A significant step has been taken toward the design of a wheelchair securement aimed at providing the wheelchair traveller with the potential for the degree of safety enjoyed by other vehicle passengers.

d) The seat module offers safe and comfortable seating to ambulatory passengers. The necessity of offering this feature in the same unit as the wheelchair securement remains questionable.

e) Transportation operators liable for the safe transport of their passengers finally have, in the wheelchair securement, a device to respond to this responsibility.

f) Problems were encountered in accommodating all electric wheelchairs because of new tire width and wheel diameters.

6. RECOMMENDATIONS

It is recommended that the design refinements, identified during the laboratory tests and evaluation program, be incorporated in a Mark II prototype, and that new prototypes be fabricated to demonstrate the new design. These design refinements include:

- Verification of rack and pinion engagement in the restraint arms.
- Use of lighter material for the arm structure.
- Widening of the unit to accommodate wider wheelchairs.
- Modifications to accommodate smaller wheels and wheels with very wide tires.
- Change of shoulder belt anchor point position.
- Modification for seat belt reel to be installed on either side of the wheelchair securement.
- Modification of bolt arrangement in wedgetrack which hold arms, so that the arrangement is accessible from center of unit.
- Elimination of the 10 cm (4 inch) horizontal adjustment to the restraint arms because by using the remaining degrees of freedom in the arm, this adjustment proved to be unnecessary.
- Verification of back and head support adjusting mechanism.

Tests in the U.S. by Minicar Limited, California, and the University of Michigan have shown that sled or crash testing is the only way to fully evaluate any restraint system. It is therefore recommended that one of the Mark II prototypes be sled or barrier crash tested with a dummy and a wheelchair to simulate real conditions.

The National Research Council in Ottawa and the Defence and Civil Institute of Environmental Medecine, a component of the Department of National Defence in Downsview, have facilities for dynamic testing as does Trasnport Canada at its Motor Vehicle Test Centre in Blainville, Quebec.

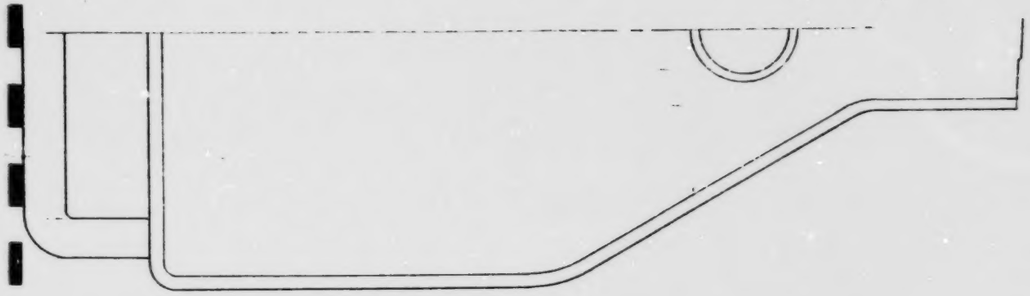
REFERENCES

1. Wheelchair tie-down/passenger seat: prototype development, by Uwe Rutenberg, Douglas Ball Inc. - Transport Canada Report TP 1821, November 1978.

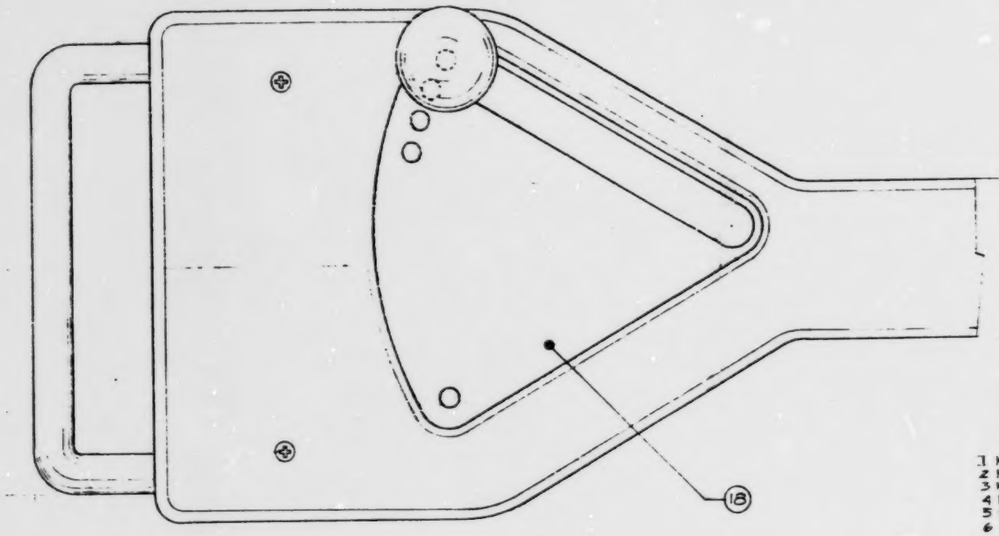
2. Wheelchair restraint system: design for multimodal transportation, by Douglas Ball Inc. - Transport Canada Report TP 2179, July 1979.

3. Transportation in Vehicles designed for Handicapped, Volume One, by Aldman, Brattgard, Hansson, October 1974, Sweden.

4. Pierce B.F. et al, Sources and Remedies for Restraint System Discomfort and Inconveniences, Prepared for the National Highway Traffic Safety Administration by Man Factors, Inc., November 1974.

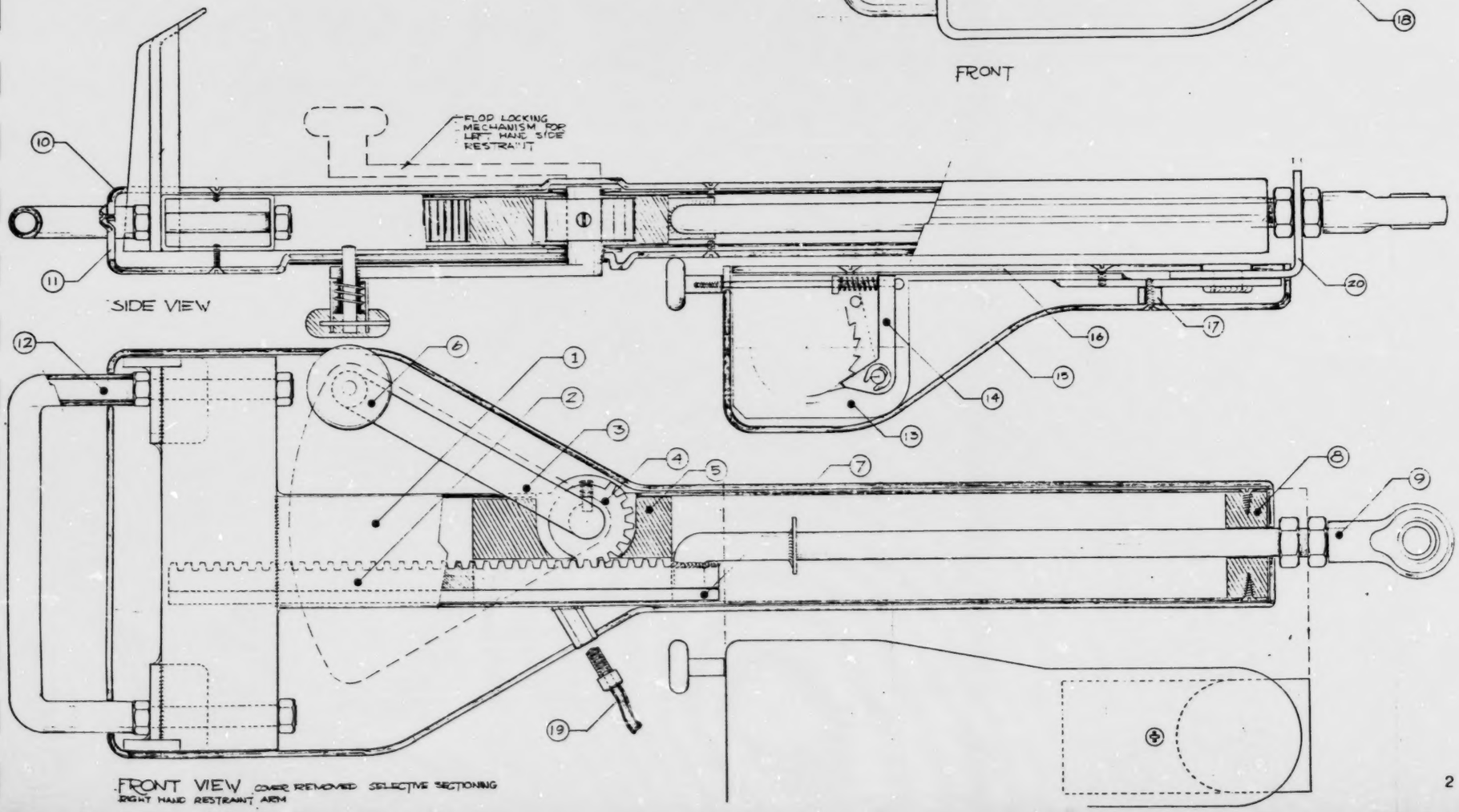


BACK



FRONT

1 MECHANISM TUBE
2 RACK - BOSTON GEAR NP 1514 12 PITCH
3 MECHANISM ADJUSTING LEVER
4 PINION - BOSTON GEAR NP 1188 12 PITCH
5 PLASTIC GUIDE BLOCK
6 MECHANISM LOCK
7 RACK SLIDE
8 RACK ROD GUIDE
9 BALL-JOINT - BOSTON GEAR
BJST-BALL HF-8
10 RESTRAINT ARM BACK COVER
11 RESTRAINT ARM FRONT COVER
12 RESTRAINT ARM HANDLE
13 SEAT BELT REEL - FUJI K-KO F-10
79 DATSUN 510 SHOULDER BELT AND
CORRESPONDING BUCKLE SYSTEM
ON ARM & TOP OF BACK REST
14 SEAT BELT REEL LOCK MECHANISM
15 SEAT BELT REEL HOUSING - FRONT
16 SEAT BELT REEL HOUSING - BACK
17 SPACER 9.5 DIA x 12.7
18 MECHANISM LOCK PLATE
19 RESTRAINT ARM SUPPORT CABLE
20 SEAT BELT REEL & BUCKLE MOUNTING
BRACKETS



SIDE VIEW

FRONT VIEW COVER REMOVED SELECTIVE SECTIONING
RIGHT HAND RESTRAINT ARM

LES DESIGNERS
DOUGLAS BALL INC.
88, RUE SAINTE-ANNE
SAINTE-ANNE DE BELLEVUE
QUEBEC H9X 1L8
TEL. (514) 457-8888

Project/Projet
WHEEL CHAIR
RESTRAINT SYSTEM

Designation/Name of drawing
ASSEMBLY DRWG.
RESTRAINT ARM

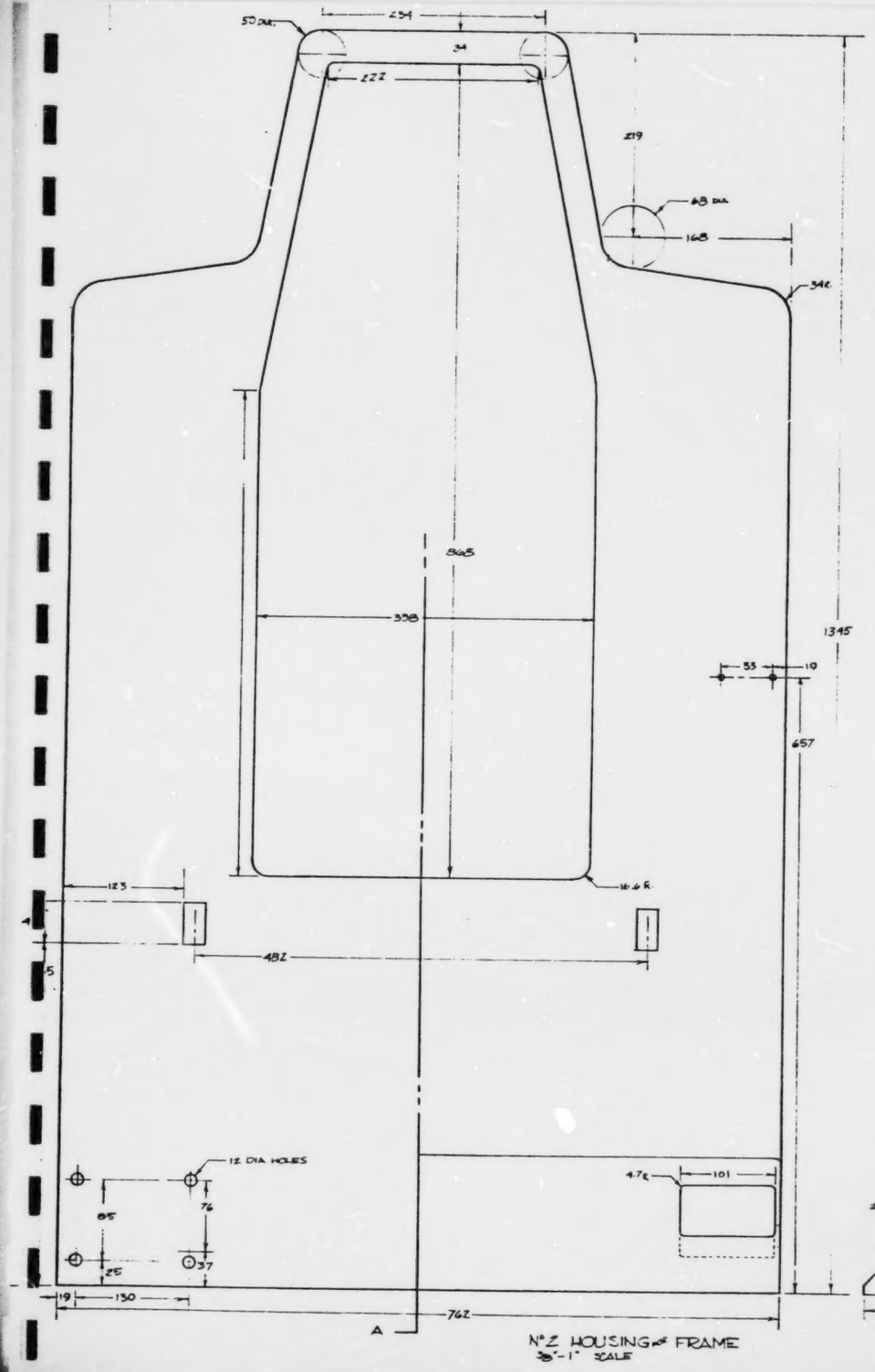
Design par/Designed by
U. RUTENBERG L. GOLDIK

Dessiné par/Drawn by
LG

Echelle/Scale
FULL

Date/Date
3·3·81

N° de dessin/No. of drawing
WRS 2 - 204



N°2 HOUSING & FRAME
3/8"-1" SCALE

SECTION A

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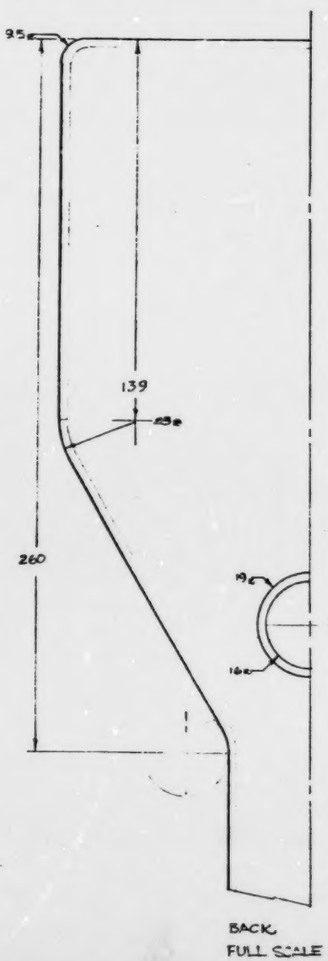
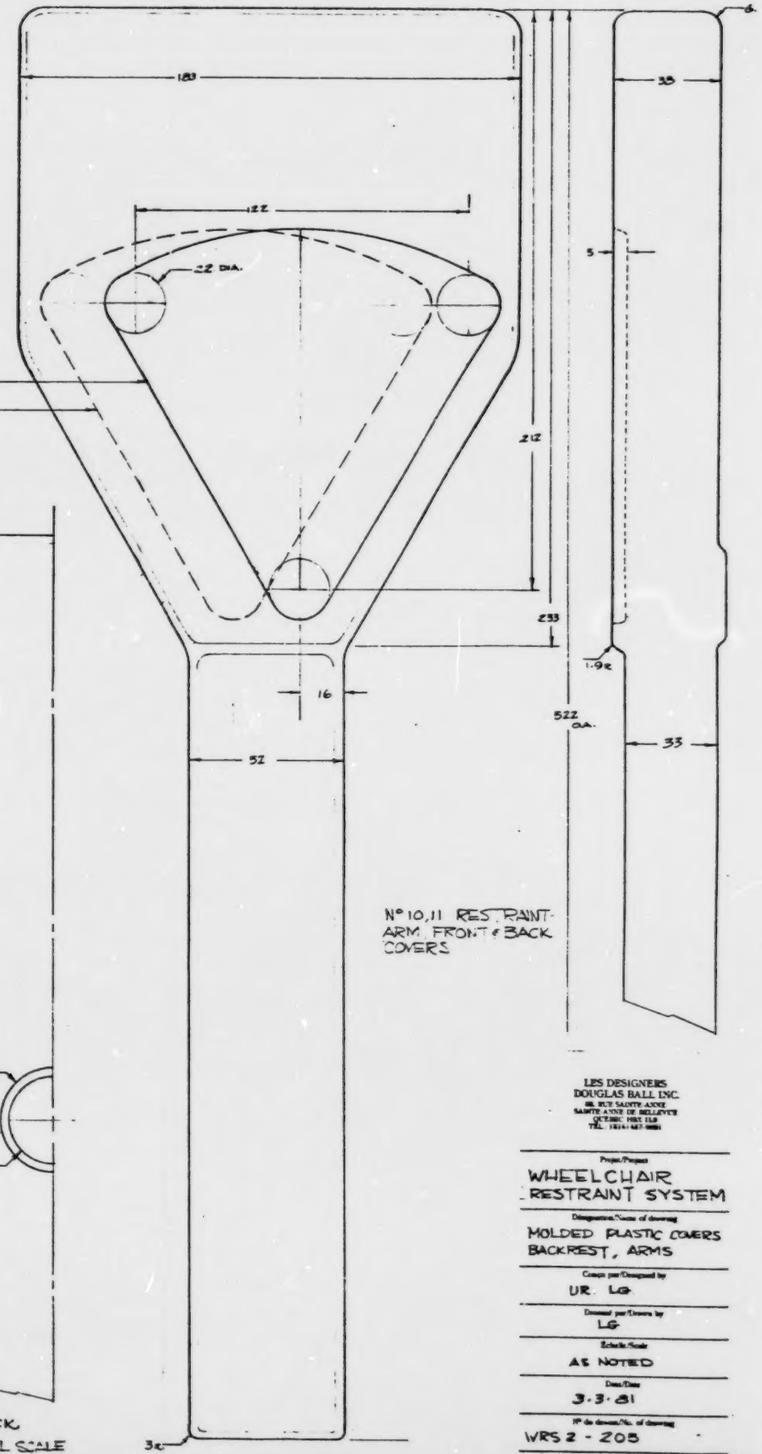


BACK
FULL SCALE



N°10,11 RESTRAINT ARM FRONT & BACK COVERS

LES DESIGNERS
DOUGLAS BALL INC.
[illegible]

Project/Projet
WHEELCHAIR RESTRAINT SYSTEM

Designation/Name of drawing
MOLDED PLASTIC COVERS BACKREST, ARMS

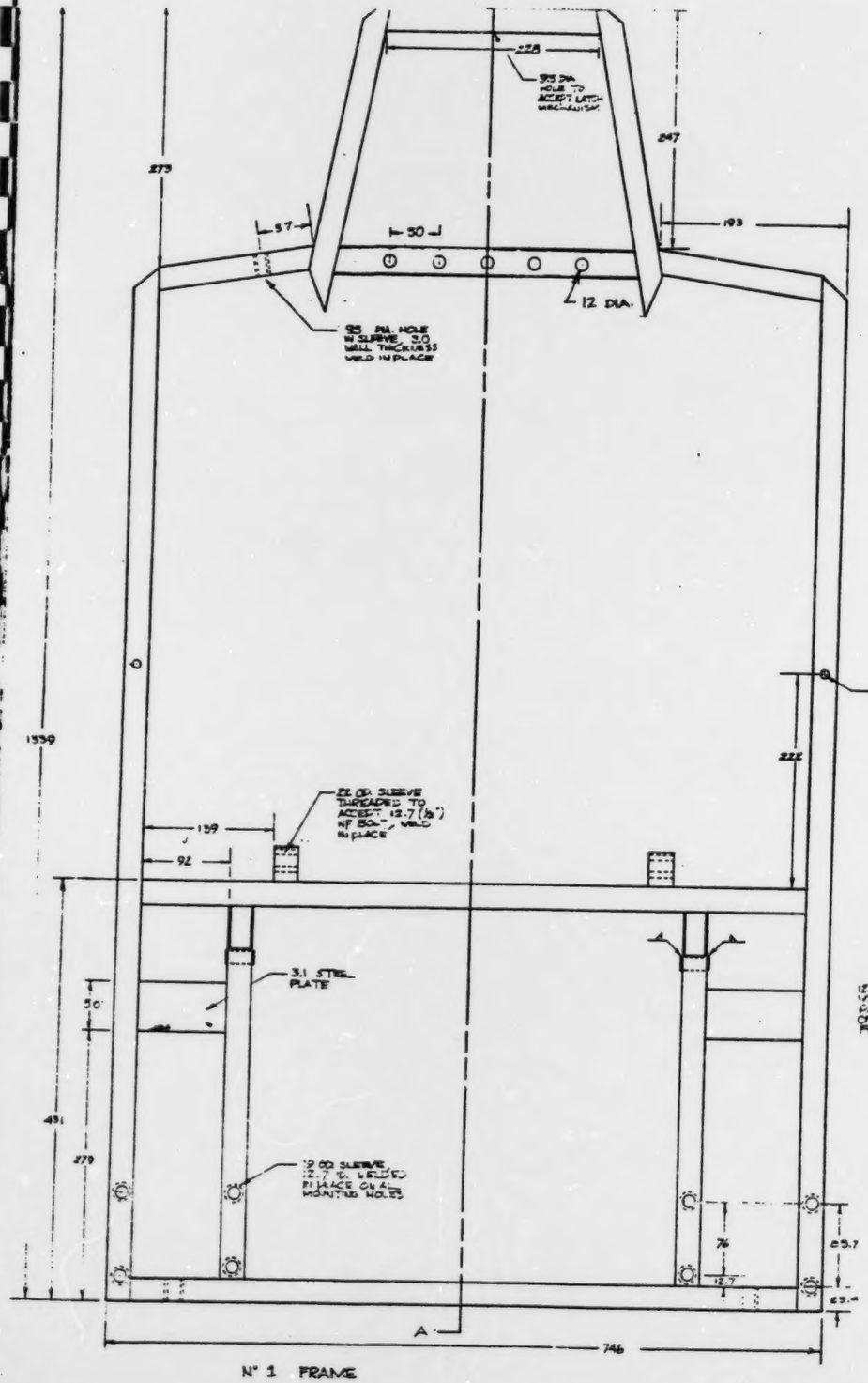
Drawn per/Dessiné par
UR. LG

Designed per/Dessiné par
LG

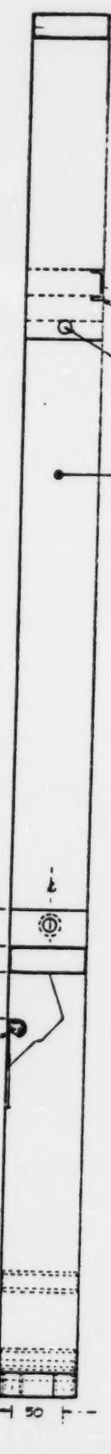
Scale/Echelle
AS NOTED

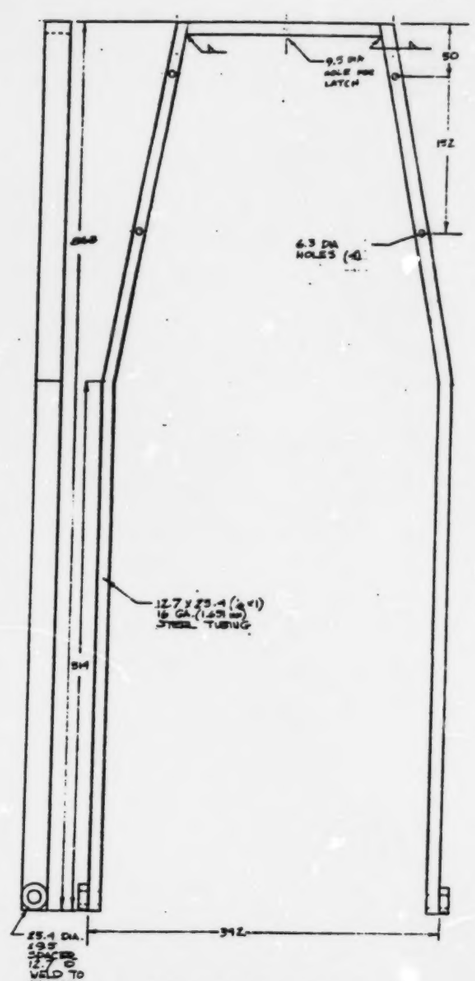
Date/Date
3.3.81

N° de dessin/No. of drawing
WRS 2 - 205

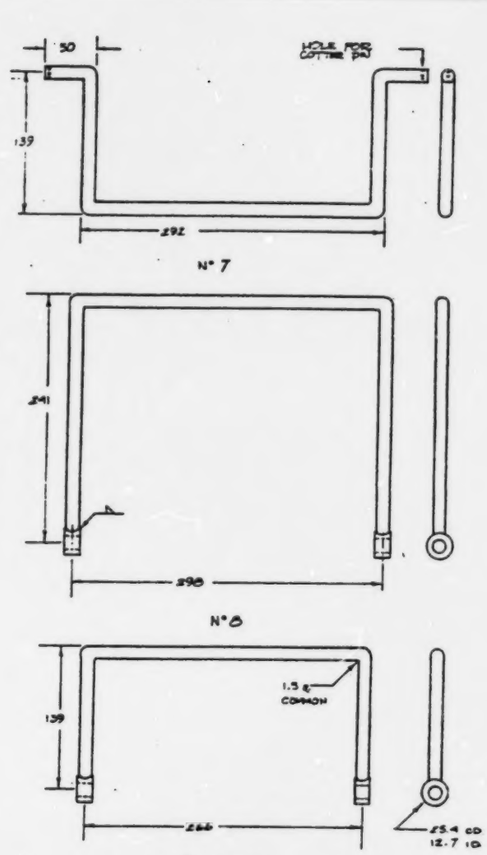


N° 1 FRAME


12x30 (½x2) CHANNEL
12.7 DIA.
NOTE:
ALL TUBING 16 GA. (1.651 mm) WALL STEEL TUBE
ALL JOINTS WELDED ON ALL SIDES.
TUBING 63.4 x 76 (1½") EXCEPT WHERE NOTED.
34
44
12.7 DIA. (½") WELDED IN PLACE WALL OF TUBE TO WELL
50

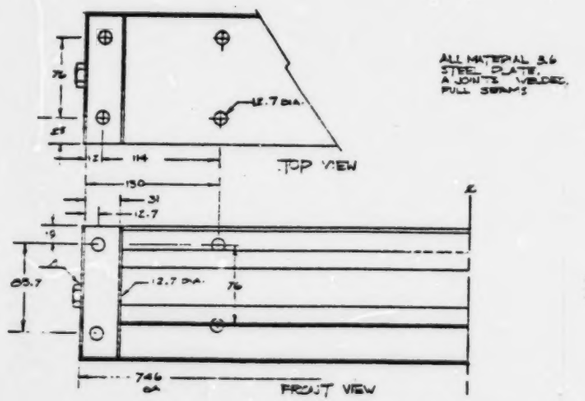

9.5 DIA HOLE FOR LATCH
50
152
6.3 DIA HOLES (4)
12.7 x 73.4 (½"x1") 16 GA. (1.651 MM) STEEL TUBING
514
63.4 DIA. 1.65 SPACER 12.7 TO WELD TO FRAME
342

N° 9 BACKREST PIVOT ARM



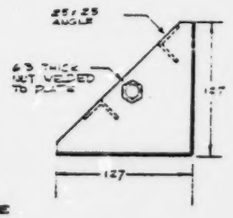
BACK REST SUPPORTS 12 MM DIA. STEEL ROD

NOTE:
ALL METAL TO BE FREE OF GREASE AND RUST. ALL METAL PAINTE DARK GREY PRIMER



N°14 RESTRAINT ARM RETAINING WEDGE

ALL MATERIAL 3.6 STEEL PLATE. A JOINTS WELDED FULL SEAMS



4

LBS DESIGNERS
DOUGLAS BALL INC.
SAULT STE MARIE ONT.

Project/Projet
WHEEL CHAIR RESTRAINT SYSTEM

Designation/Name of drawing
BACK REST COMPONENTS

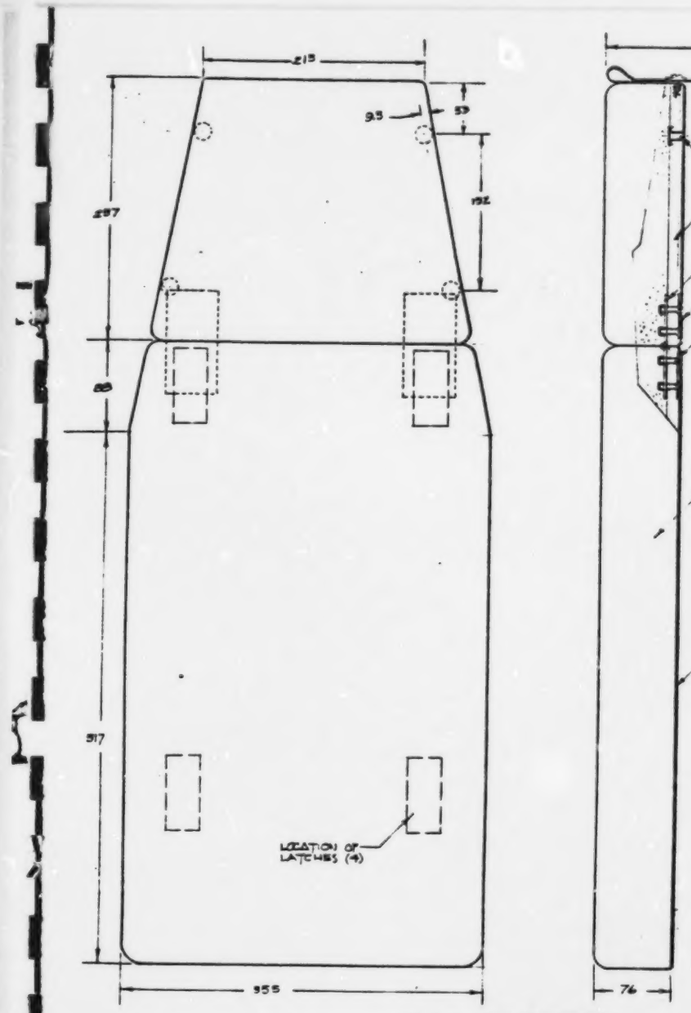
Drawn per/Dessiné by
UR LG

Checked per/Dessiné by
LG

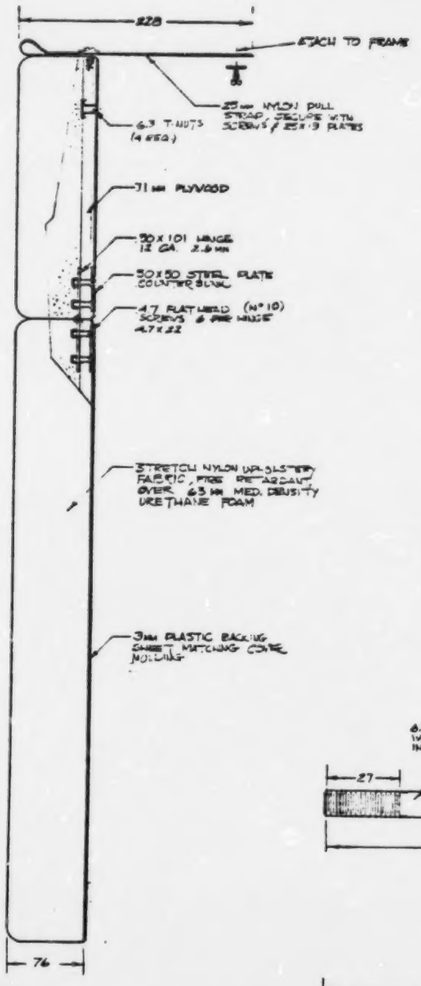
Scale/Echelle
3/8" - 1"

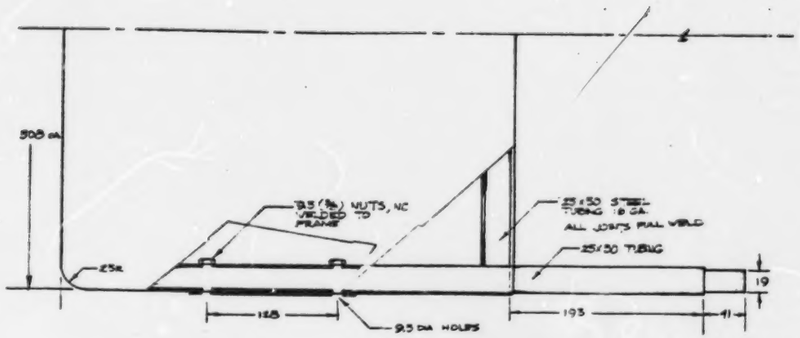
Date/Date
3-3-81

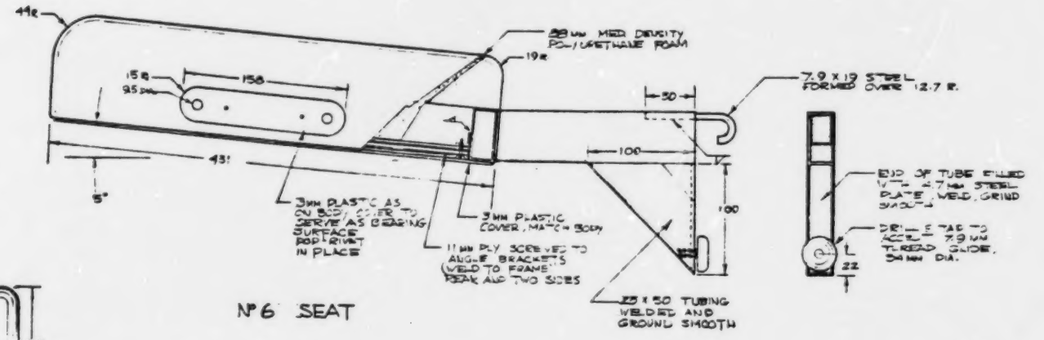
N° de dessin/No. of drawing
WRS 2-206



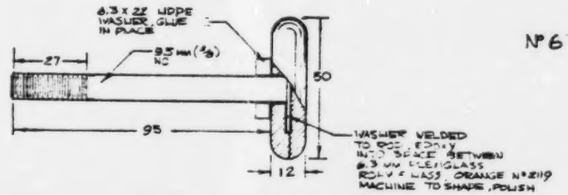
N° 3, 4 HEAD & BACKREST


228
ATTACH TO FRAME
25 mm NYLON PULL STRAP, SECURE WITH SCREWS & 25 x 19 PLATES
6.3 T-NUTS (4 REQ.)
19 mm PLYWOOD
50 x 101 HINGE 12 GA. 2.0 mm
50 x 50 STEEL PLATE COUNTERBORE
4.7 FLAT HEAD (N° 10) SCREWS & PRE HINGE 4.7 x 22
STRETCH NYLON UPHOLSTERY FABRIC, FIRE RETARDANT OVER 63 mm MED. DENSITY URETHANE FOAM
3mm PLASTIC BACKING SHEET MATCHING COVER MATERIAL

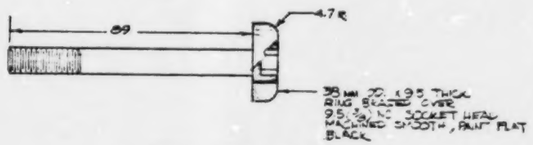



44R
88 mm MED. DENSITY POLYURETHANE FOAM
19R
15R
9.5 DIA
158
30
7.9 x 19 STEEL FORMED OVER 12.7 R.
100
100
431
5°
3mm PLASTIC AS ON BODY COVER TO SERVE AS BEARING SURFACE POP RIVET IN PLACE
3mm PLASTIC COVER, MATCH BODY
11 mm PLY SCREWED TO ANGLE BRACKETS WELD TO FRAME REAR AND TWO SIDES
25 x 50 TUBING WELDED AND GROUND SMOOTH
END OF TUBE FILLED WITH 4.7 mm STEEL PLATE, WELD, GRIND SMOOTH
DRILL & TAP TO ACCEPT 7.9 mm THREAD GLIDE, 34 mm DIA.
22

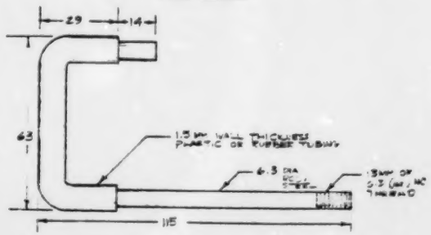
N°6 SEAT


6.3 x 22 HDPE WASHER GLUE IN PLACE
9.5 mm (3/8) NC
27
95
50
12
WASHER WELDED TO ROD, EPOXY INTO SPACE BETWEEN 6.3 mm FIBREGLASS ROD W/ 4 MASS ORANGE N°2119 MACHINE TO SHAPE, POLISH

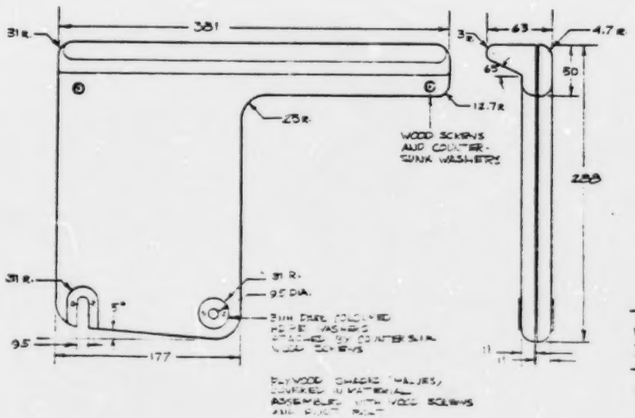
ARMREST LOCKING KNOB 2 REQ
FULL SCALE



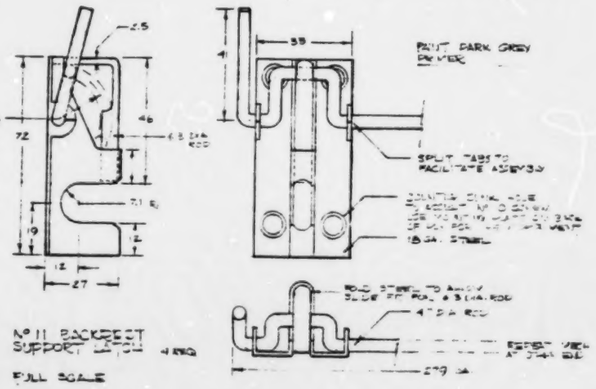
ARMREST PIVOT BOLT 2 REQ
FULL SCALE



N° 12 RESTRAINT ARM STORAGE HOOK
2 REQ.



N°5 ARMREST 2 REQ.



N°11 BACKREST SUPPORT LATCH 4 REQ.
FULL SCALE

LES DESIGNERS
DOUGLAS BALL INC.

WHEEL CHAIR RESTRAINT SYSTEM

BACK REST COMPONENTS SEAT BACKREST

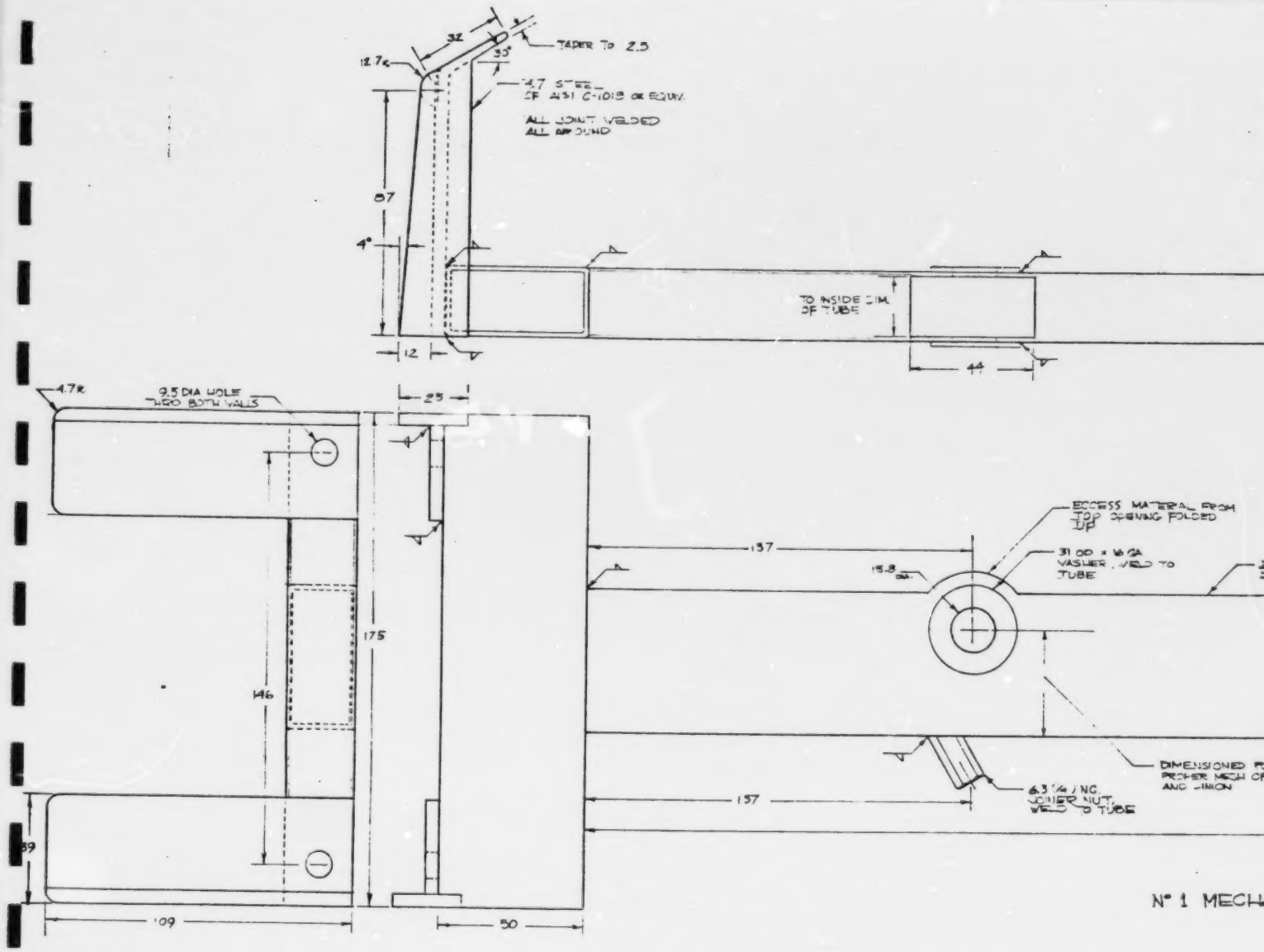
UR LG

LG

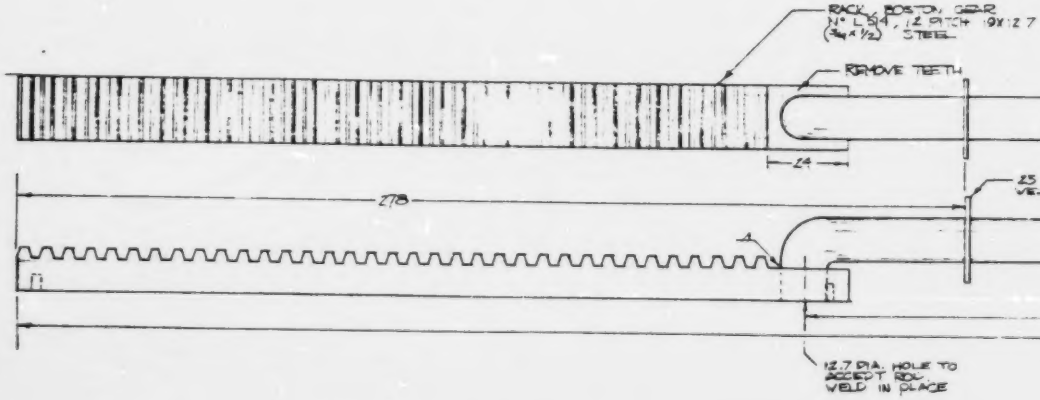
3/8" - 1"

3 · 3 · 81

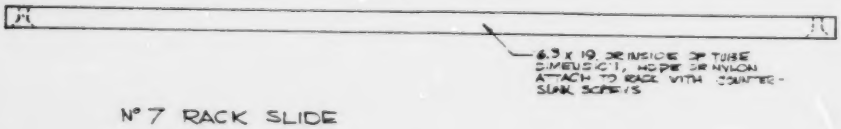
WRS 2 - 207



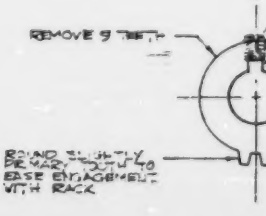
N° 1 MECH

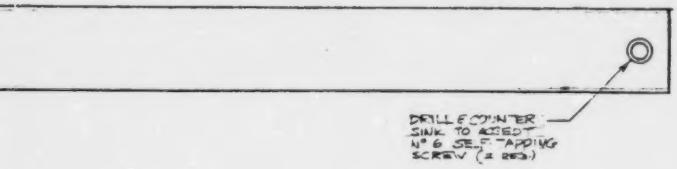

RACK, BOSTON GEAR N° L514, 12 PITCH 19X12.7 (3/4 x 1/2) STEEL
REMOVE TEETH
24
25 OD WASHER WELD IN PLACE
278
309
529
12.7 DIA. HOLE TO ACCEPT ROD, WELD IN PLACE

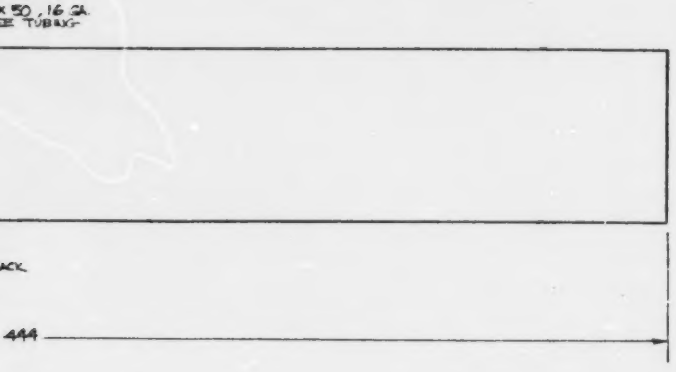
N° 2 RACK



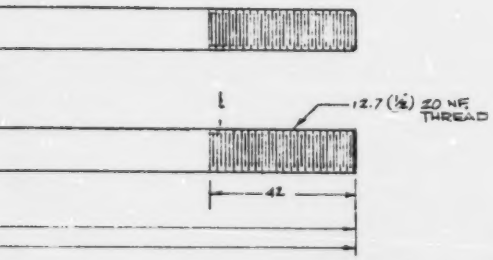
N° 7 RACK SLIDE

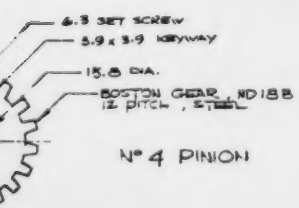






NISM TUBE





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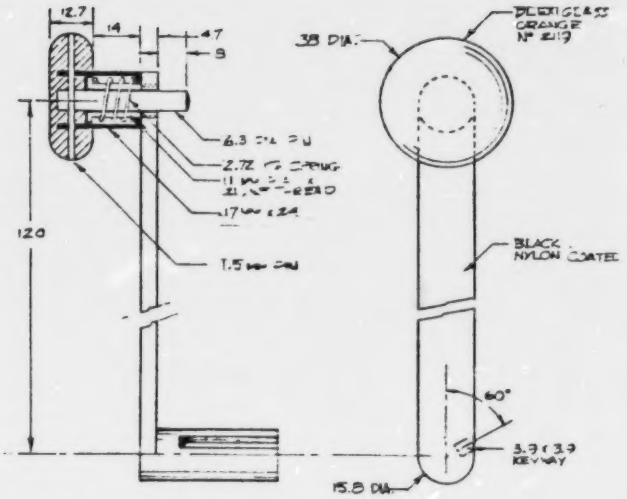
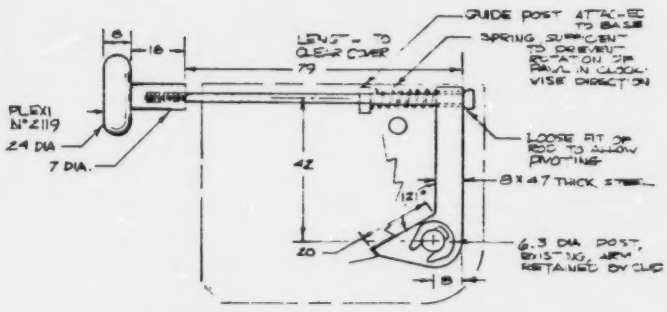


Nº3 MECH. ADJUSTING LEVER
Nº6 MECHANISM LOCK

ALL INERTIA LOCKING MECH REMOVED FROM REEL LEAVING RETURN SPRING



Nº SEAT BELT REEL LOCK MECHANISM

LES DESIGNERS
DOUGLAS BALL INC.
[illegible]
TEL. [illegible]

Project/Projet
WHEEL CHAIR RESTRAINT SYSTEM

Designation/Name of drawing
RESTRAINT ARM COMPONENTS

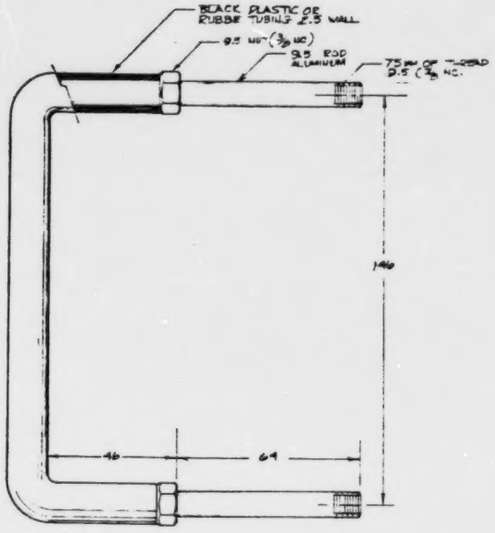
Design par/Designed by
UR LG

Dessiné par/Drawn by
LG

Echelle/Scale
FULL

Date/Date
3·3·81

N° de dessin/No. of drawing
WRS 2 · 208



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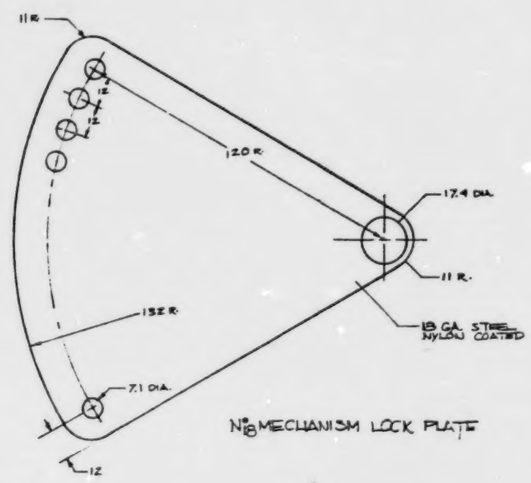

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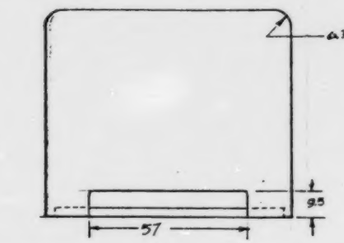

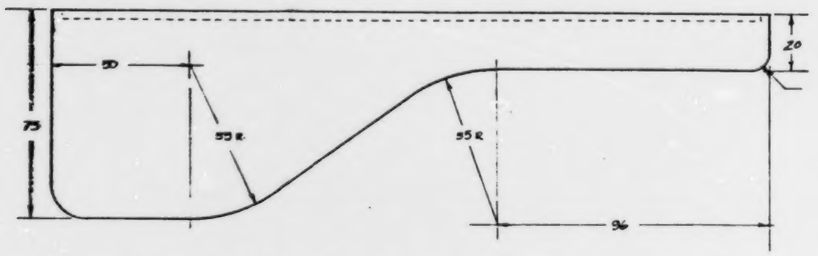

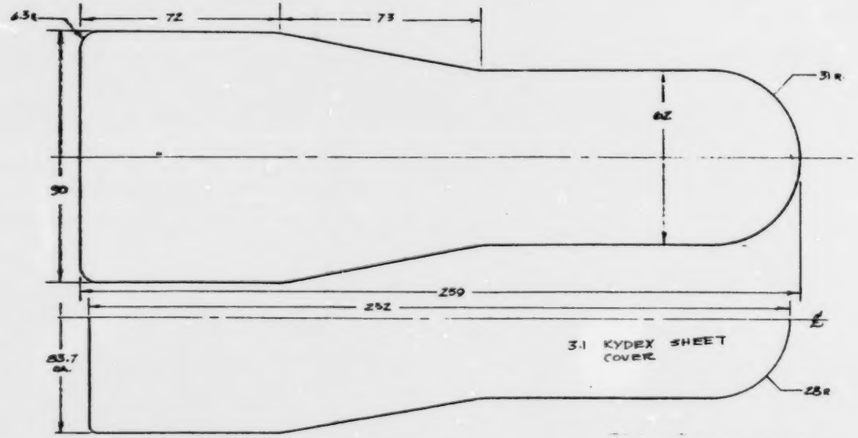

N°15,16 SEAT BELT REEL HOUSINGS

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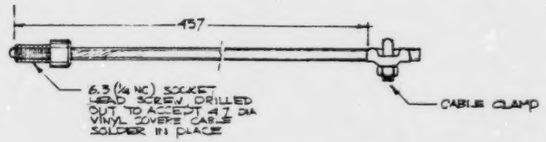
COLOUR - GREY N° 52001
W. N° 52002



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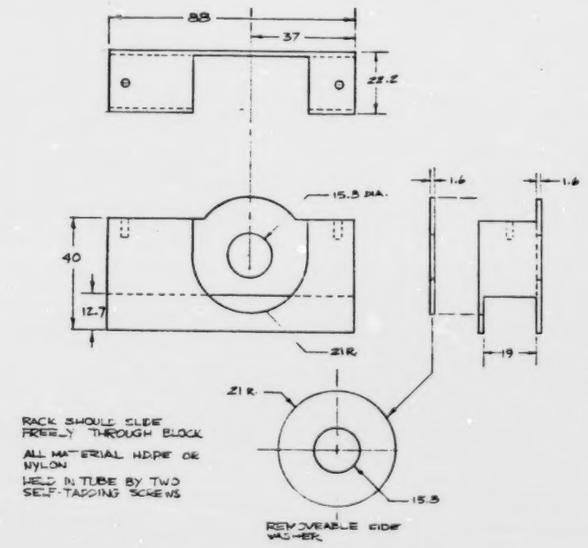

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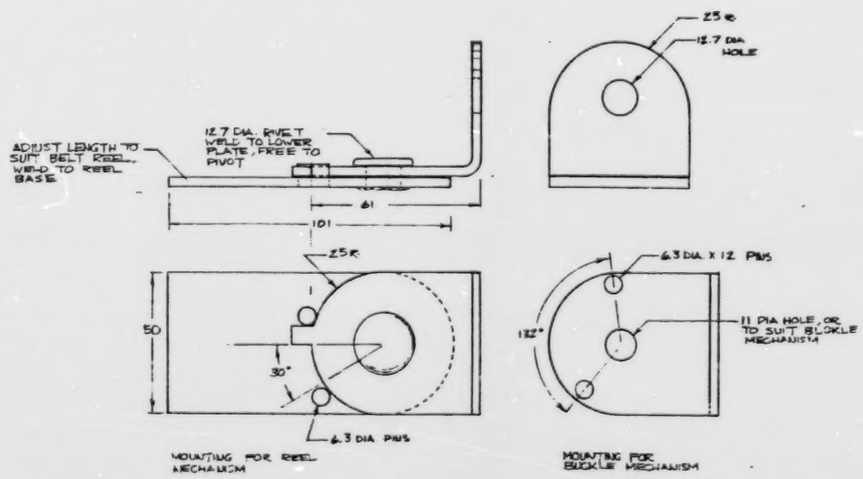

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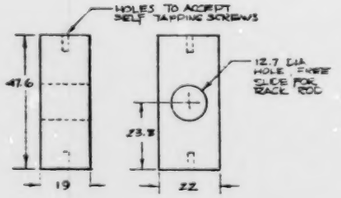

N° RACK ROD GUIDE

HDPE, DELRIN OR NYLON

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Project/Projet
WHEEL CHAIR RESTRAINT SYSTEM

Designation/Name of drawing
RESTRAINT ARM COMPONENTS

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UR. LG

Dessiné par/Drawn by
LG

Echelle/Scale
FULL

Date/Date
3·3·81

N° du dessin/No. of drawing
WRS 2 - 209

APPENDIX B· REPORT OF LABORATORY TESTING OF THE WHEELCHAIR RESTRAINT SYSTEM

PROJECT OUTLINE

WHEELCHAIR OCCUPANT RESTRAINT SYSTEM

Introduction and Background

Douglas Ball Incorporated are under contract to the Transport Canada Research and Development Centre to develop and test a system to restrain a wheelchair and its occupant in a vehicle in the event of a crash. The restraint system consists of several modular elements which can be combined for different applications:

1. The basic element, called "Wedgetrack", is 71 cm (28") wide and 15 cm (6") high. Its triangular shape stops the wheels from rolling back. Two restraint devices slide on a track and are adjustable to the different chair dimensions. The element is bolted to the floor.

2. A bulkhead, 41 cm (16") high and 10 cm (4") deep, can be added to the "Wedgetrack"; it has a lap belt and provides an additional stop for the wheels.

3. To this, a head and shoulder support unit can be added to complete a safety unit. The backrest is pivoting in order to bring it as close as possible to the passenger back and lock it there. A shoulder belt is part of this unit and provides, together with the lap belt, a complete safety system. The complete width of 71 cm (28") is carried up to 94 cm (37") in order to have a stop for the handlebars.

4. The fourth and last element of the system is a special seat to be added when a disabled, but not wheelchair bound, passenger is to be accommodated. It uses the same belt system and has pivoting armrests to allow easy access and egress.

The concept was designed as a steel structure bolted to the floor or to the wall. The structure is covered by a plastic shell. Head, shoulder and armrest are upholstered as is the seat.

Test Methodology

The system is a seat back and seat belt system designed to restrain an occupant independently of a device used to restrain a wheelchair. The Canadian Motor Vehicle Safety Standards regulate the design and performance characteristics of occupant restraint systems by specifying tests for anchorage strength, belt webbing strength and anchorage location. These tests are regularly performed on seat belt systems provided by vehicle manufacturers and the test procedures are well established. It thus appears logical to test the system to the requirements of CMVSS 207 Anchorage of Seats, CMVSS 208 Seat Belt Installations, CMVSS 209 Seat Belt Assemblies and CMVSS 210 Seat Belt Assembly Anchorages.

During an impact, a belt restraint system is loaded by the occupant to a severity depending on the acceleration profile experienced by the vehicle. The pelvic belt will restrain much of the weight of the body

and the torso belt prevents rotation about the pelvic belt. These belts and anchorages are tested by developing a static tensile load in a cable and applying the loads to the belts through pulling blocks, which simulate the curvature of the body. Naturally, the loads are applied so that they occur simultaneously as they would in impact. The load is of particular interest in this test series and a load cell has an additional feature not found in the majority of occupant restraint systems in that it must also restrain a wheelchair. Therefore an additional load will be applied through the center of gravity of the wheelchair. Three thousand pounds is considered an appropriate load.

This testing will provide data concerning the strength of anchorages and system design under static loading conditions. It would be desirable to supplement the static testing with dynamic sled testing at some future date.

Test Method

A suitable test structure will be prepared by the contractor.

1. This program will begin by determining the weight and center of gravity of the wedgetrack, bulkhead, backrest and wheelchair.

2. The wedgetrack, bulkhead and wheelchair will be mounted in the forward facing direction on the vehicle test structure using load cells at the four lower mounting locations. A force of 909 kg (2000 lbs) will be applied evenly to the frame of the wheelchair through its center of gravity. If permanent deformation of the wheelchair seems likely, an alternate means of loading the wheelchair restraint arms will be used.

The two forces will be maintained for 10 seconds, the anchorage loads will be recorded and the forces released.

3. The backrest will be bolted securely to the bulkhead and to an upper anchorage. Load cells will be used for the upper anchorage. The force in 2 will be restored and simultaneously a force of 1363 kg (3000 lbs) will be applied through a pelvic body block to the pelvic belt at an angle of 10 degrees above the horizontal, at an onset rate of not more than 13636 kg/sec. (30000 lbs/sec.), so as to attain the 1363 kg (3000 lbs) force in approximately 10 seconds and a 1363 kg (3000 lbs) force will be applied through an upper torso body block to the torso belt at the same onset rate. The anchorage loads will be recorded and a force equal to 20 times the weight of the wedgetrack, bulkhead and seat back will be simultaneously applied through the center of gravity of the assembly. The anchorage loads will be recorded and the forces removed.

4. The wheelchair will be removed and the seat installed.

5. A force equal to 20 times the weight of the seat will be applied through the center of gravity of the seat. After the anchorage loads are recorded, the force of 20 times the weight of the backrest, bulkhead and wedgetrack will be restored. After the loads are recorded, the forces on the pelvic and the torso belts will be restored. Once the loads are recorded, the forces will be removed.

6. If there has not been severe deformation of the assembly, the entire system will be removed and re-installed in a rearward facing direction. A force of 20 times the weight of the system will be applied through the center of gravity of the system. Simultaneously, a force of 1491 kg (3280 lbs) will be applied through a point 34 cm (13.5") above the seat cushion. The loads on the anchorages will be recorded and the forces removed.

T E S Report Number: C291-1

TESTING OF A WHEELCHAIR OCCUPANT RESTRAINT SYSTEM

December, 1980

Prepared For

DOUGLAS BALL INC.

Sainte-Anne-de-Bellevue, Quebec

By

T E S Limited

Ottawa, Canada

INTRODUCTION

This report describes the procedures used and the results obtained during testing of a wheelchair occupant restraint system designed by Douglas Ball Inc. of Sainte-Anne-de-Bellevue, Quebec.

The restraint system is for use in vehicles such as vans and is intended to restrain a wheelchair and its occupant in the event of a crash. The system also incorporates a special seat which can be added when a disabled, but not wheelchair bound, passenger is to be accommodated.

The purpose of the testing was to determine the strength of the restraint system under predetermined static loading conditions and to gather data concerning forces at the restraint mounting locations.

PROCEDURES

Load cells were to be utilized, at selected restraint attachment points, in order to gather data concerning the loads at these locations. The first step in specifying appropriate load cells was to perform a theoretical analysis of the restraint system under the various required loading conditions. This analysis (which contained several necessary assumptions regarding belt angles, rigidity of the restraint, etc.) was performed and provided approximate maximum loads, at the various mounting locations, for each of the different restraint configurations and loading conditions.

Once these maximum loads were known, a search was made of commercially available load cells of the appropriate capacity. It was envisaged that either an instrumented bolt or washer would provide the best type of load cell for this application. The search indicated that commercial load cells were either not available within the required time frame or that the cost of such cells was beyond the instrumentation cost limit of the project. As a result, it was decided to fabricate the load cells.

Three load cells were fabricated from 12.7 mm diameter bolts. The bolts were machined down to 10 mm diameter and two strain gauges mounted on diametrically opposite sides of the machined area. The wires from the strain gauges were fed out through a groove machined through the bolt threads. One of the load cell bolts (and a standard bolt) is shown in Figure 1. Tests were performed on a similarly machined bolt to determine the yield and ultimate strengths of the load cells. The load cells were calibrated with a simple tensile load and then calibrated

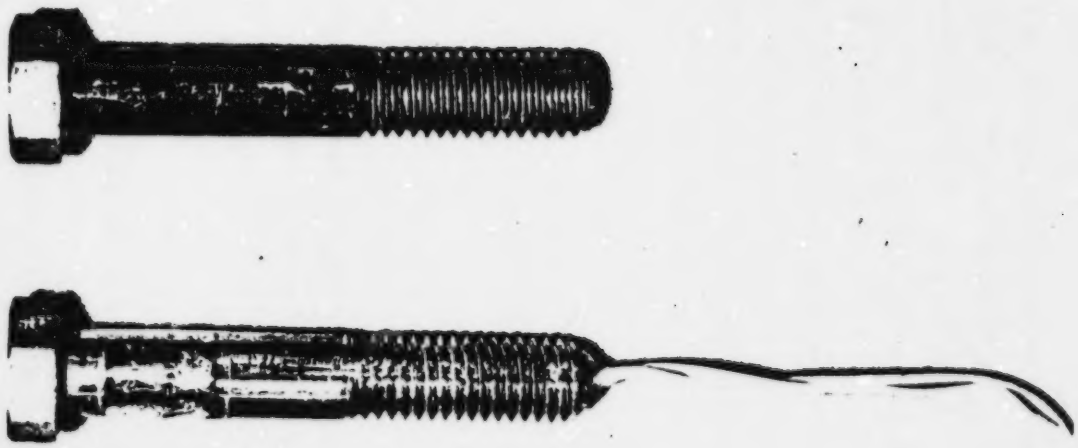

FIGURE 1

STANDARD BOLT AND LOAD CELL BOLT

with different pre-loads. From this information, the torque (and hence the pre-load) to be utilized in assembling the load cell bolts in the restraint system was selected.

Prior to testing, the tightness of all fasteners in the restraint system was verified. The restraint was mounted in our test rig and various brackets fabricated to secure the restraint in position and to apply the required loads using calibrated hydraulic cylinders. Loads were transferred to the pelvic and torso belts using body blocks supplied by the Transport Canada Motor Vehicle Test Centre. The general layout of the test apparatus can be seen in Figures 2 and 3.

Four separate tests had initially been specified. However, as testing proceeded, it became impractical to follow the original test program because various restraint system components failed. The following three tests were performed.

In test #1 (see Figure 2), only the wedge-track and bulkhead were utilized. They were mounted in the test rig and the wheelchair locked in position with the two restraint devices. The wheelchair brakes were applied. The body block was placed in the wheelchair and the pelvic belt fastened about it. Two cylinders were used to apply loads. The first was used to apply a load (forward) to the centre of gravity of the wheelchair and the second to pull on the pelvic belt. Only one load cell was used during this test. It was installed at the lefthand (as related to a seated, forward-facing passenger) attachment point of the bulkhead.

The test plan was to load the wheelchair to 909 kg and record the load cell reading. Then the pelvic belt would be loaded

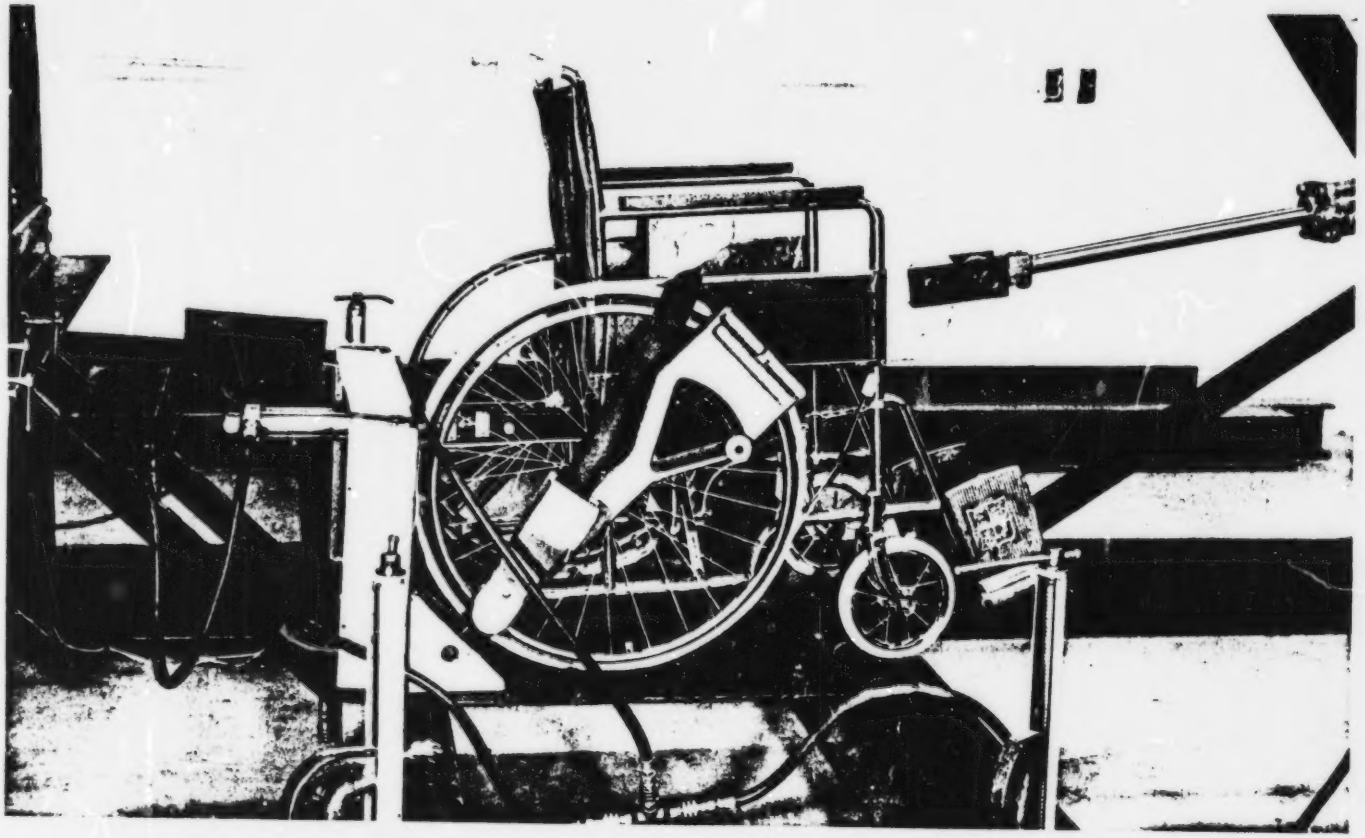

FIGURE 2

TEST #1 - WEDGE-TRACK, BULKHEAD AND WHEELCHAIR

to 1363 kg and the load cell reading recorded. All loads were to be applied slowly. The test would be concluded by releasing the loads.

In test #2, the backrest element was added to the wedge-track and bulkhead. The backrest was secured in the test rig (as shown in Figure 3) and the special seat installed in the restraint, in place of the wheelchair. The two body blocks were placed in position and the pelvic and torso belts fastened about them. Four cylinders were used to apply the loads. The first was used to push forward on the seat at its centre of gravity; the second, to push forward on the restraint system at its centre of gravity; the third, to pull on the pelvic belt; and the fourth, to pull on the torso belt. Two load cells were utilized during this test, at the locations where the attachment point loads would be the highest. One was installed at the lefthand attachment location of the bulkhead (same as test #1), while the other was installed at the upper righthand attachment location of the backrest element.

The test plan was to load the seat to 170.4 kg and record the load cell readings. Then, additionally load the restraint system to 863.6 kg and record the load cell readings. Finally, while maintaining the above loads, both the pelvic and torso belts would be loaded simultaneously to 1363 kg and the load cell readings recorded. The test would be concluded by releasing the loads.

In test #3, the restraint system (with the seat installed) was laid on its back on a concrete floor. A wooden torso (which is an approximate representation of a 84 kg male) was placed in the seat and strapped to the seat bottom and back support.

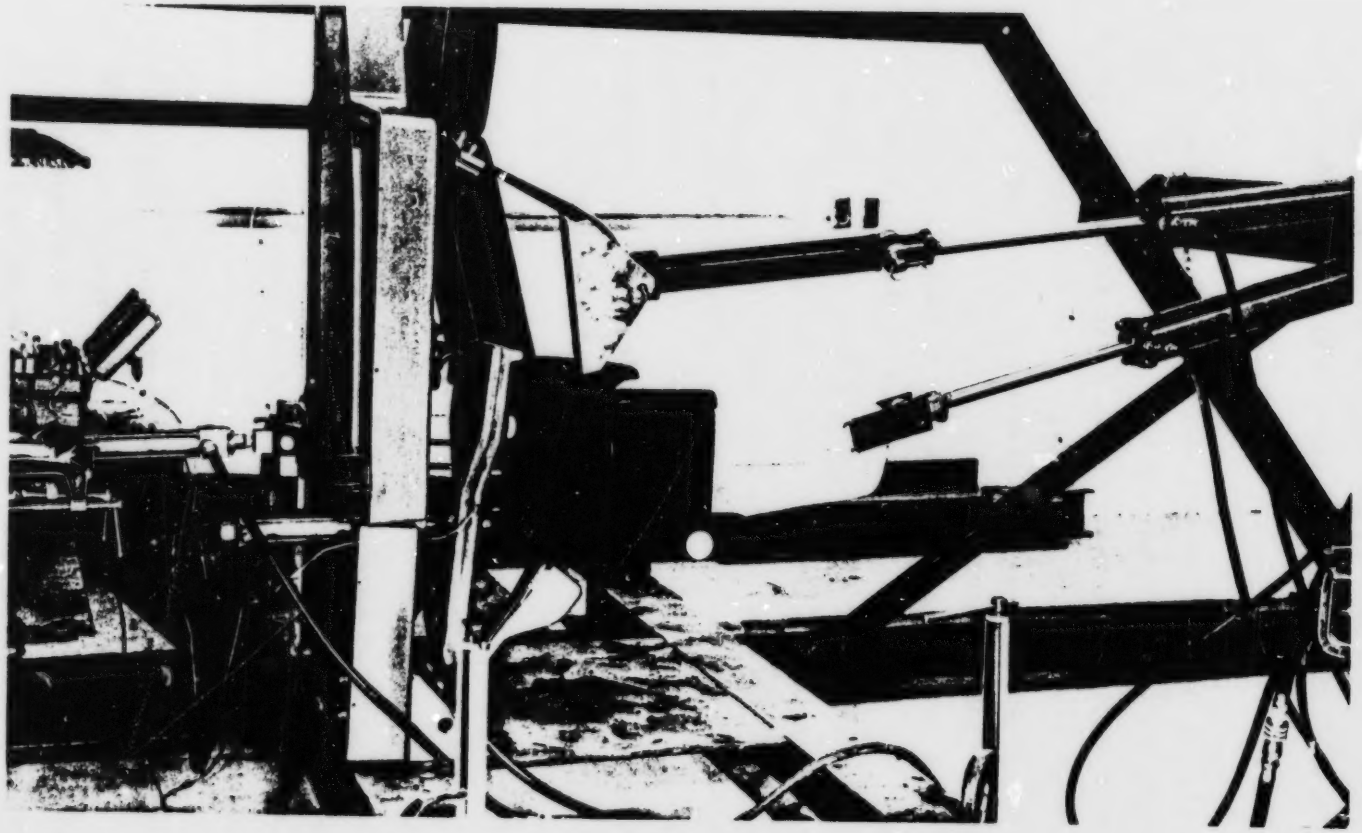

FIGURE 3

TEST #2 - WEDGE-TRACK, BULKHEAD, BACKREST AND SPECIAL SEAT

A hydraulic cylinder was used to apply a load to the centre of gravity of the wooden torso. The line of action of this load was 21.5 cm above the seat cushion. No load cells were utilized. The test layout can be seen in Figure 4.

The test plan was to load the wooden torso to 1491 kg and then release the load.

Tests #1 and #2 were documented photographically with colour slides and black and white prints. Test #3 was documented with black and white photographs.

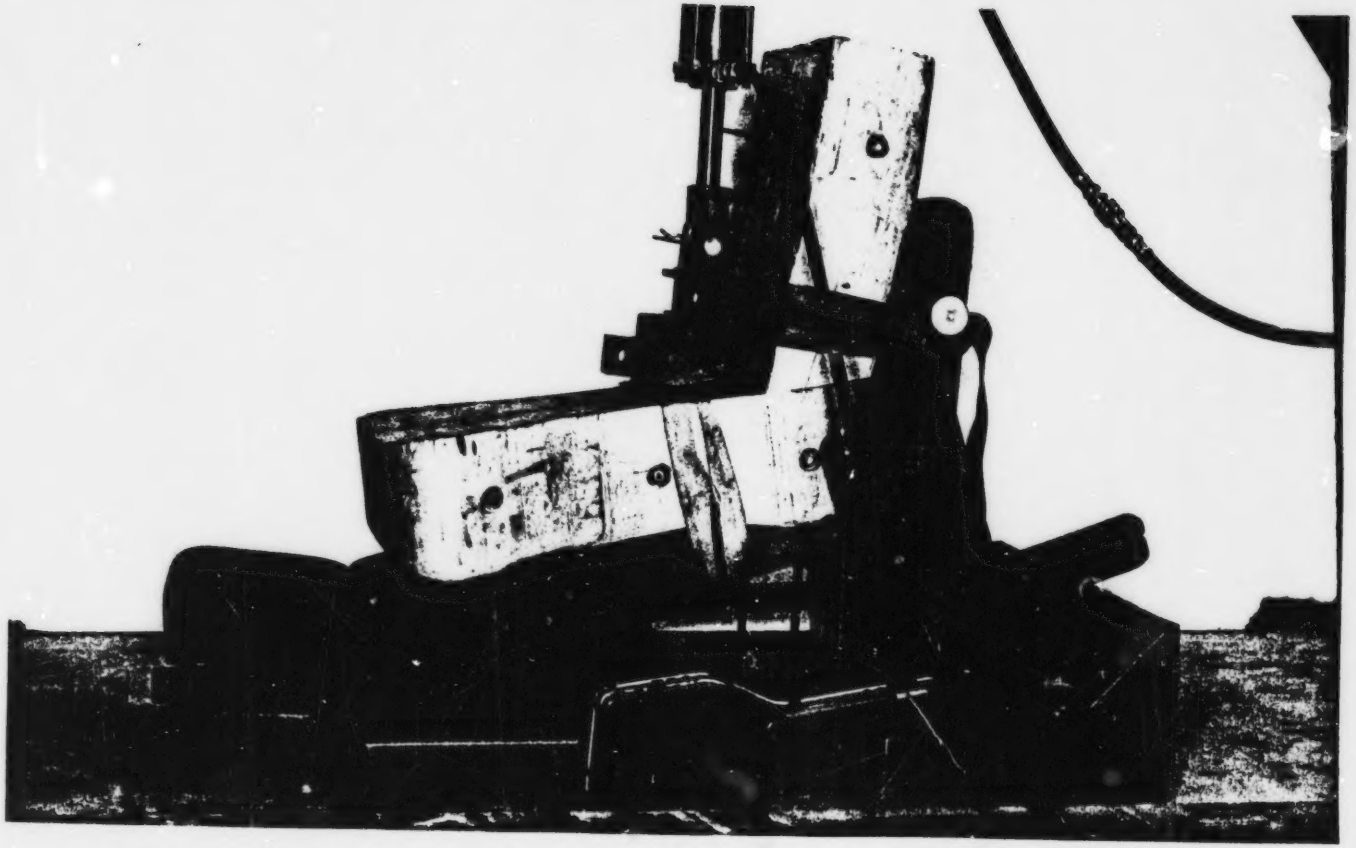

FIGURE 4

TEST #3 - RESTRAINT SYSTEM, SEAT AND WOODEN TORSO

RESULTS

Theoretical Analysis

The results of the theoretical analysis indicated that the highest attachment loads would occur at two locations. One was at the lefthand attachment point of the bulkhead to the vehicle floor. This area of the restraint is subject to loads from both the pelvic and torso belts. The other location was at the upper righthand attachment point of the backrest to the vehicle vertical surface. This area of the restraint is subject to loading by the torso belt. At each of these locations, the maximum theoretical load that would be experienced during the various tests was approximately 1363 kg.

Load Cell Calibration

A bolt identical, in material and machined size, to the load cells was tested to destruction in a tensile testing machine. The results showed that the yield strength of the load cells was 2864 kg and that the ultimate strength was 4136 kg. Calibration of the load cells under a simple tensile load showed that all three load cells were virtually identical. The load cells were then calibrated for three different pre-loads which correspond to bolt torques of 13.66, 34.15 and 40.98 newton-metres. A pre-load of 34.15 newton-metres was chosen because it would be adequate to prevent shear in the load cell bolts and would permit an applied load of approximately 2364 kg to be measured before the load cell would yield.

Restraint System Tests

During test #1, the wheelchair was to have been loaded to 909 kg. This load corresponds to a 20g loading of a 45 kg wheelchair. A wheelchair weighing 45 kg was considered to be typical of the heaviest wheelchair that would be used with this system. However, when a load of approximately 418 kg was reached, the wheelchair appeared to be on the verge of incipient failure and no further load was applied. It should be noted that this particular wheelchair weighed approximately 20 kg and a 20g loading is equivalent to 400 kg. While maintaining the 418 kg load, a load was then applied to the pelvic belt. As this load was being applied, the two restraint devices (which clamp over the wheels of the wheelchair) extended out to their full length in a ratcheting manner. When the restraint devices were extending, the short cables that help support the devices were pulled free of the bulkhead. At a pelvic belt load of approximately 895 kg, the belt stitching failed at the point where the belt is attached to the male portion of the seat belt buckle and the belt pulled free. The plastic ring on the male buckle also broke during loading. In addition, the sides of the wheelchair were considerably damaged by the seat belt during loading. At the failure load of 895 kg, the load cell reading corresponded to an applied load at the attachment point of approximately 454 kg.

Before test #2 could be performed, it was necessary to secure the seat belt around the male buckle where the stitching had failed. This was accomplished by clamping the belt between two flat steel plates after looping it around a piece of steel rod. This clamping arrangement can be seen in Figure 3 at the torso belt buckle.

During test #2, the seat was loaded to 170 kg and then in addition, the restraint system was loaded to 863 kg. At this point, both the pelvic and torso belts were put under load and the load slowly increased. At a belt load of approximately 441 kg, the load cell at the bulkhead attachment point read approximately 1045 kg and the load cell at the backrest attachment point read 434 kg. As the load on the belts was increased, the backrest load cell bolt unexpectedly went past its yield point.

The test proceeded and the load on the belts was continually increased. At a belt load of approximately 1173 kg, the torso belt broke near the torso body block. Prior to failure, the frame of the backrest was being bent forward in the area of the load cell by the load being applied at the torso belt buckle attachment. In addition, there was movement at the interface between the backrest element and bulkhead (see Figure 3). At the belt failure load of 1173 kg, the bulkhead load cell reading was approximately 1609 kg.

After the loads were removed, other damage to the restraint was evident. There was minor deformation of the seat arm attachment hooks, causing the front of the seat to drop down slightly. The long bolt that holds the lefthand restraint device in position was also slightly bent. In addition, the brackets used to attach the seat belt anchorages to the restraint devices were both bent. Where the torso belt was anchored to the backrest frame, the anchorage was very loose as a result of local buckling of the frame under the attachment bolt.

During test #3, the load was slowly increased on the wooden

torso. The lower back support rod bent, fractured and then became disconnected from the back support. The upper back support rod also bent and disconnected, and the hinge between head support and the back support disconnected at the head support. The test was stopped at a load of approximately 688 kg.

When the lower back support rod was examined, it was found to be fractured at two locations. However, it was obvious that at these locations, the rod had been previously cracked when it was heated and bent during fabrication.

DISCUSSION

The testing of the wheelchair occupant restraint system has indicated that the system is conceptually adequate but has several deficiencies in its component parts. Modifications to these components should enable the restraint system to pass all of the specified loading tests.

The components that require attention and possible modification are:

- The two restraint devices which ratcheted to full extension under load.
- The seat belt system which was an area of failure in tests #1 and #2.
- The mechanisms for holding the head and back supports in position.
- The seat attachment hooks, restraint device bolt and seat belt anchorage brackets, which bent during testing.
- Certain areas of the backrest frame that bent and/or buckled under load.

An important point to be considered is the proper assembly and installation of the restraint system in a vehicle. During test #2, it appears that movement took place at the interface where the backrest element and bulkhead are bolted together. During the theoretical analysis, an assumption was made that the entire restraint frame would act as a rigid body. However, if only a small relative movement occurs between the elements at the interface, the frame tends to rotate by bending about the backrest attachment bolts. That is to say, the interface connection acts as a hinge point rather than a rigid connection

and places abnormal loads on the anchor points. This is undoubtedly what occurred in test #2 effectively putting a larger load than anticipated in the bolts (one of which was a load cell). As a result, when the belt loads were increased, it was possible for the load cell to yield. The method of mounting the backrest must ensure that the frame of the backrest, from the attachment bolts upward, is secured in a manner that will prevent any rotational movement of this portion of the backrest frame. This might require redesign of the interface connection to ensure rigidity or the use of additional attachment bolts at the top of the backrest frame to carry the extra load due to hinge action at the interface.

Considering the assumptions which had to be made to simplify the calculations, there was reasonably good agreement between the theoretical loads at the attachment points and those measured during the tests with the load cells. It was unfortunate that the upper attachment point load cell yielded during test #2 which meant that the loads at this point could not be measured accurately at failure. However, this did point out the need for the restraint system to be assembled and installed carefully in a vehicle and the fasteners to be correctly torqued. As a result of failures to various restraint components, none of the tests could be completed, thus, the maximum attachment point loads could not be measured. However, judging from the loads that were measured, the maximum attachment point loads are probably in the order of 1818 kg.

As the restraint system did not pass any of the loading tests, it is recommended that testing be repeated when the necessary modifications are made to the restraint. It is also recommended that a new seat belt be used for each test where the belt is loaded, since loading of the belt webbing material in one test may adversely affect its strength in a subsequent test.

Ergonomic Evaluation of Multimodal Restraint System

by

Ruth M. Heron, Ph.D.,
Methodological Consultant

February 1981

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INTRODUCTION

This report deals with the methodology and results of a field test of the multimodal restraint system described earlier in Transport Canada Report TP 2179, July 1979. The trial installation, in a van for transporting the disabled, accommodated two types of adult passengers, those in wheelchairs and the ambulatory disabled. As it is the driver who performs the operational tasks with the system, the major focus of the evaluation involved a third population, the driver operators. The aim of the study was to gain objective information as to how the restraint system might be modified so as to render it as ergonomically suitable as possible to members of all three populations.

METHOD

Subjects

Subjects were 8 driver-operators, along with 21 wheelchair and 6 ambulatory regular passengers, of the M&O Bus Lines (Handicab) Limited, a transportation service for disabled individuals in Ottawa. A breakdown of the wheelchair passengers by sex, age, and type of disability appears in Table 1. Table 2 contains similar data for the ambulatory passengers. Descriptive data were not sought for their drivers as this information did not appear to be relevant to design deficiencies which affect operational performance.

Instruments

For a comprehensive approach, it was necessary to design three questionnaires, one for the driver-operators (Form DO), and one for each of the two types of passengers (Forms W and A for wheelchair and ambulatory passengers, respectively). All three instruments are attached as Appendix I. A general feature of these questionnaires is a tone which treats the subject as capable of making good judgment and is willing to respond in the interest of bettering the system. This approach was taken in view of prior information to the effect that members of the three populations would be highly co-operative.

Form DO

The purpose of this instrument was to force the emergence of operational design defects. In order that such defects could be precisely defined, the various performance tasks required for getting a passenger in and out of the device were segmented into operations. There was a total of 15 operations for wheelchair passengers, 12 for ambulatory passengers, as set out in Table 3.

For each operation, the driver was asked to state (a) whether or not a difficulty exists, (b) the nature of such difficulty, and (c) a suggested solution.

Forms W and A

As the passengers do not operate the system in question, questions on Forms W and A were designed to elicit information relating to the experience of using it, such as feelings of security, comfort, and support. Form W includes an item regarding appearance. Even-numbered scales were used for these dimensions to offset the tendency to select the midpoint. Four-point scales were considered sufficient for the size of sample to be selected and for the type of gross information required.

The general approach was to try to zero in on why a maximum rating or a positive answer was not given to key items. An open-ended format was adopted for most of the follow-up questions in the interest of obtaining spontaneous responses, a strategy considered appropriate for what appeared to be a co-operative population.

Table 1

Breakdown of Wheelchair Subjects
by Sex, Age, and Type of Disability

Sex	Male					Female					
Disability \ Age	<20	20-35	36-50	51-65	>65	<20	20-35	36-50	51-65	>65	Total
Muscular Dystrophy		1									1
Residual Polio									1		1
Spinal Lesion		2				1					3
Multiple Sclerosis			2							1	3
Cerebral Palsy			1				1				2
Arthritis									1		1
Stroke				1							1
Amputee								1	1		2
Heart										1	1
Total	0	3	3	1	0	1	1	1	3	2	15

Table 2

Breakdown of Ambulatory Subjects

by Sex, Age, and Disability

Sex	Male		Female		Total
Age / Disability	51-65	>65	51-65	>65	
Muscular Dystrophy			1		1
Multiple Sclerosis	1				1
Arthritis				1	1
Stroke	1	1			2
Injury			1		1
Total	2	1	2	1	6

Table 3

Operations Required for getting Passengers
in and out of the System

In	In
1. Back wheelchair into system	1. Unlock arm rest if necessary
2. Pull restraint arms forward	2. Help passenger into seat
3. Place hooks on tires	3. Lock armrest
4. Lock hooks	4. Adjust headrest
5. Adjust backrest	5. Pull lap belt across occupant
6. Adjust headrest	6. Fasten lap belt
7. Pull lap belt across occupant	7. Pull shoulder belt across occupant
8. Fasten	8. Fasten shoulder belt
9. Pull shoulder belt across occupant	
10. Fasten	
Out	Out
11. Release shoulder belt	9. Release shoulder belt
12. Release lap belt	10. Release lap belt
13. Release restraint arms	11. Release armrest if necessary
14. Park arms	12. Help passenger out of seat
15. Wheel passenger out	

Unlike the driver-operators, passengers were not advised of the superior safety aspects of the restraint system as it was felt that, to do so, would invite social desirability effects.

Design and Sampling Considerations

The question of how to secure the information from users was deliberated at some length. It was believed that drivers were willing to distribute and collect forms. However users could not be expected to undergo the discomfort of trying to complete a questionnaire during a trip, nor to be delayed with the form on reaching their destinations. Some thought was given to centralized telephone administration, a method known to produce orderly data at low refusal rates. However, given the positive information regarding the willingness of users to supply information, there seemed to be little risk in opting for a take-home procedure. The instructions on the front page of Forms W and A go so far as to encourage respondents to make several trips before returning their completed questionnaires to the driver.

In developing a sampling strategy, a number of facts regarding the van operation were considered in terms of the purpose of the study. The van company services approximately 480 people a day between the ages of 20 and 80 years, about 90 of whom are regular passengers going to and from work. The wheelchair/ambulatory split for both regular and non-regular passengers is close enough to even at 45% to 55% respectively. About 30 drivers work a 6-day week to keep a fleet of 18 vans servicing these passengers.

As the intent of the study was not to test specific hypotheses, but rather to expose operating and psychological defects in the system, it was clearly unnecessary to tap large samples of the three populations. It was reasoned, in fact, that about 20 well completed questionnaires from each group would suffice. Budgetary constraints dictated that only one van could be outfitted as a test vehicle containing one installation for wheelchairs and one seat system. Still, by rotating drivers, it was clear that as many as 30 drivers could be exposed to the test vehicle over a two-week period, a large enough population of co-operative members to produce 20 completed questionnaires. The small sampling requirements further enabled a decision to be made to confine the passenger population to regular users, a restriction introducing some control over effects due to riding in the van per se, which would likely be less dominant in the more frequent users.

With rather optimistic expectations of reasonable return rates, 30 Forms DO, 50 Forms W, and 50 Forms A were prepared for distribution.

Procedures

The test vehicle operated for 50 days, beginning in December 1980 and ending in January 1981.

Each driver of the test vehicle was given a Form DO and fully briefed regarding the aims and procedures of the study. On each trip,

the driver distributed Forms W and A to regular wheelchair and ambulatory passengers respectively, as they were leaving the van. Users who completed the questionnaire gave it to a driver, as requested, on a later trip.

RESULTS AND DISCUSSION

Data Reduction

Responses to each of the three types of questionnaire, Forms DO, W, and A, were coded (Appendix II) and tabulated (Appendix III). It will be noted from the code sheets in Appendix II that "0" has been used for explanatory items if the subject had selected the optimal response on the preceding item. The convention of using "9" to indicate a missing value has been adhered to. However its use in the coding scheme for Forms W and A has been extended to inlcude cases in which a subject had indicated that a particular part of the system, say the shoulder belt, had not been used.

Sample Characteristics

As can be seen from Tables 1 and 2, only 8 driver-operators, 15 wheelchair passengers, and 6 ambulatory passengers returned a questionnaire. These exceedingly low return rates are likely due to one or more of two factors: (a) the overestimation of the willingness of the relevant individuals to participate, and (b) the timing of the test run in the month of December when many people are burdened with holiday preparation.

Because of this low return rate, it is not possible to make confident statements about the nature of the passenger populations. The sample characteristics may be discerned in Tables 1 and 2. From these tables it is clear that the wheelchair sample spreads itself across age and disability categories, while the ambulatory respondents are confined to a few disabilities and to ages 51 years and over. It is impossible to say whether these differences reflect population characteristics or differences in tendencies to respond.

Data for Driver-Operators: Wheelchair Passengers

Manoeuvering in and out

Half of the 8 driver-operators apparently experienced no difficulty backing wheelchairs into the system. However, 2 reported that the system was not wide anough for the chairs they were handling (new electric), another that the chair was difficult to center, and a fourth that there was simply not enough room to manoeuver. Wheeling the chair out of the system appears to have been virtually problem-free, although one operator did indicate that the chair tends to get caught on the restraining arms.

Restraint arms

Problems relating to the restraint arms seem to be confined mainly to operations necessary on boarding. Difficulty was experienced by 4 operators in pulling the arms forward, and by 5 both in placing them on the tires and in locking them. The pull-forward operation was effortful for the wall-side arm. Placement of the arm hooks on the wheels of the

chair was, of course, not possible with the wide electric wheelchair; however, in other cases, the difficulty with this operation was that the brakes of the chair were in the way. The single suggested improvement was to widen the unit. Comments regarding the locking mechanism suggest that it is too stiff. One operator reported that the arms hooks tend to slip and suggested rounding them.

Releasing the arms for exit of the passenger was reported as being difficult by only one operator. However his explanation, that it is hard to reach the arm next to the wall, suggests that he misinterpreted the item and was perhaps referring to the parking operation. No other operator experienced difficulty in parking the arms.

Backrest and headrest

No reports of difficulties in adjusting either the backrest or headrest were obtained. However, one operator commented that these features do not provide additional comfort to the passenger.

Lap and shoulder belts

Pulling the lap belt across the wheelchair occupant was problematic for 6 of the 8 drivers. Half of these pointed out that the belt is on the wrong side of the chair and that, in any case, it is hard to release. Other comments are to the effect that the belt is hard to reach and that it locks, the latter possibly referring to the tendency of the belt to lock when the occupant moves. Suggestions for remedial measures include provision of more working space, elimination of the pull-out lock on the belt, and adjustment to the locking mechanism such that it operates in only one direction.

A single operator reported difficulty in fastening the belt, along with the explanation that he had to lean over the occupant in order to perform this operation. Release of the lap belt from the chair occupant was carried out with ease by all respondents.

Pulling the shoulder belt across chair occupants was reportedly effortful for 4 operators, these explaining that the pull-lock is not easily released. This reason was given also by one operator reporting a problem in fastening the belt, but he seems to have been trying to indicate that, if the belt could not be pulled out, it could not be fastened.

Again, no reports of difficulty in releasing the shoulder belt from occupants were obtained.

Data for Driver-Operators: Ambulatory Passengers

Armrest and seat

No operator reported difficulty in removing and locking the armrests back into place. However reports from ambulatory passengers suggest that most did not need to take advantage of this feature.

Therefore there is a possibility that the armrest feature was not adequately tested.

Only one respondent reported difficulty in getting a passenger in and out of the seat, explaining that the seat was too low. Certainly elderly passengers, especially if disabled, could have trouble lowering themselves into and rising from a low seat. Thus having the seat raised might tend to take some of the load off the operators whose assistance might otherwise be required in these cases.

Headrest

One operator suggested redesigning the headrest to eliminate excessive movement which interferes with its adjustability. The fact that other operators made no such comment may have been because this part of the system was infrequently used.

Lap and shoulder belts

Comments regarding the belt system are similar to those cited earlier for wheelchair passengers and, therefore, will not be repeated. The incidence of reported problems was somewhat lower for the ambulatory passengers, possibly because it is easier to strap in a person when the awkward bulk of the wheelchair is absent.

Additional comments

Only one operator availed himself of the space at the end of the questionnaire to make suggestions about other aspects of the system. His remark, that many ambulatory passengers have trouble entering the van by the wheelchair lift and that a separate more suitable entrance would overcome this problem, does not have specific relevance to features of the restraint system. Still, it does point up the necessity of considering <u>all</u> ergonomic factors which might affect use of the system.

<u>Data for Wheelchair Passengers</u>

Appearance of the system

The obtained mean rating for acceptability of the system's appearance by wheelchair passengers is 2.87 out of a possible four. Only 3 of the 15 respondents in this group rated the system's appearance as very acceptable; of the remainder, 9 found it <u>fairly</u> so, while one found it fairly <u>un</u>acceptable and 2 found it <u>very</u> unacceptable.

Only the last 3 of these gave reasons for their low ratings. These were, respectively, that the system does not fit the chair, that it looks as if it could damage the chair, and that its back takes up too much room. The first reason reflects a misunderstanding of the question. The second may represent a reaction to the rather formidable mechanical features of the restraining arms. The last is difficult to understand as the interior of the van is large and spacious. However, it is possible that some passengers in a van for the disabled would have a

sense of incarceration, strapped down as they are and sealed in with the metallic crunch of shutting doors and folding lift in their ears. Such an experience could distort perception of the size of the system relative to the space within the van.

No respondent offered suggestions as to how the appearance of the system might be improved, possibly because there is very little that could be done in this respect, except perhaps to introduce congenial colours. Making passengers aware that the system is designed to protect them in the event of a collision might tend to mitigate any negative psychological reactions to its appearance.

Sense of security

The mean rating obtained for the sense of security scale is a rather high 3.13. Only 6 subjects did not give the maximum rating for this item, 2 of which were in electric wheelchairs which were too wide to be accommodated by the system and, accordingly, selected the lowest rating. Of the remaining 4 subjects, 2 reported feeling fairly secure, one fairly insecure, and one very insecure. One of these expressed concern that the system might damage the wheels of the chair, another that the chair might tip back. Comments such as these reflect fears which likely arise from a lack of knowledge or understanding of forces and could, therefore, be addressed by giving passengers information about what the system does and how it operates to afford them safety.

Experienced movement

Of the 4 respondents who reported feeling "a little" movement, 2 were those who had electric wheelchairs and were not properly secured by the restraint arms. One of these described the experienced movement as "back and forth". No details of experienced movement were given by the 2 subjects not in electric wheelchairs. It is possible that, in these cases, the motion of the vehicle was experienced as movement of the chair.

Backrest

The backrest was not used by 8 wheelchair passengers, 4 of whom were prevented from doing so by bags on the back of their chairs. A fifth subject explained that he felt no need to use the backrest while a sixth, probably referring to the headrest, said that he did not use "it" because it was too far from the head to be of any use. Of the 7 who used the backrest, only 2 reported that it did not give good support; however both gave reasons which relate to comfort rather than support, eg., "too much pressure", and "pushed into back". It is likely true, though, that if the backrest is not comfortable, it will not give rise to a feeling of good support.

The mean comfort rating for the 7 who used the back support is only 2.14 out of a possible 4.00. Although the backrest was fairly comfortable for 4 respondents, it was very uncomfortable for the other 3. No reasons were given as to why discomfort was experienced, but it seems

clear from the comments regarding support that the contour of the backrest was not satisfactory for these occupants.

Headrest

Only 4 subjects appear to have used the headrest, all reporting that it gave them good support. However, only one of these gave this part of the system the maximum rating for comfort, the other 3 rating it as fairly comfortable.

Of the 11 respondents who did not use the headrest, 2 (neither of whom reported carrying a bag) said that it was too far back. Therefore, although a bag would prevent a passenger from using either the backrest or headrest, lack of use of the headrest does not seem to be due primarily to the presence of a bag. Rather it appears, along with the backrest, to be tied to system construction which corrective modification could likely render more useful.

Lap and shoulder belts

Full support by the lap and shoulder belt was reportedly experienced by 8 respondents. Only one of these indicated that he felt discomfort from wearing the support system, apparently because both lap and shoulder belt were too tight.

Of 3 subjects who reported <u>not</u> feeling fully supported by the belt system, one had not used the lap belt because it would not go around the waist; he felt discomfort from the shoulder belt because it was too close to the neck and made him feel tied in. The other two subjects may have felt unsupported because they did not wear the shoulder belt for some reason. One of the two reported discomfort from the lap belt because it was too high over the chair.

Of the remaining 4 subjects, 3 did not respond to any of the lap and shoulder belt items, possibly because the support system was not used. The fourth did not respond to items regarding support but must have worn the shoulder belt because he remarked that it was too tight.

Despite this spotty responding, items in this section of the questionnaire nevertheless generated sufficient information to suggest that both lap and shoulder belt need to be lengthened.

Additional comments

Of the 15 wheelchair passengers, only 5 used the space at the end of the questionnaire. Their comments are paraphrased below:

1. Some mechanism for helping passengers out would be helpful.
2. Removing the seat behind the driver would provide better visibility.
3. I enjoyed the service but do not like to ride facing the back of the van.
4. The restraint system has a lot of merit, especially for those

handicapped who have little or no control over their limbs.
5. The restraint system seemed to serve its purpose very well.

The first item is not interpretable since it is the responsibility of the driver to get passengers out of the restraint system area, as well as out of the van.

As will be seen later drivers had virtually no difficulty getting wheelchairs out of the system area. The second item may reflect the psychological effect referred to earlier. Being packed into a van and tied down has potential for creating a sense of imprisonment which, in turn, could alter perception of properties of the van's interior. Although it is true that, in the case at hand, one system was installed directly behind the driver, it overlapped the open space there only to a small extent. Moreover, as the second system was installed diagonally opposite the first, the view of the user of the second system would be unobstructed. Finally the very large side windows in the van in question admit great amounts of light and make it possible for riders to see outside. In sum, the physical features of the system and its environment would appear to be more than adequate with respect to visibility. Negative psychological effects, which may prevail despite this fact, can probably be offset with information about safety properties of the system.

The third comment is a reminder that motion sickness is a real possibility for some individuals when riding backwards. Therefore, if it is not possible to arrange the seating otherwise, it would be wise for driver-operators to check with passengers regarding tendency toward motion sickness before placing them in the van. The last two comments appear to be subjects' ways of expressing appreciation for the effort and service provided on their behalf.

Data for Ambulatory Passengers

Backrest

Only one of the 6 ambulatory passengers reported that the backrest of the seat system did not give good support. His explanation, that it was too close to the front, may be related more to comfort than to support. The fact that this passenger also reported that the backrest was very uncomfortable because it was not at the right angle, supports this interpretation. A rating of somewhat uncomfortable was given by another ambulatory passenger along with a comment to the effect that the backrest is not the right shape. The other 3 passengers found it only fairly comfortable, but did not give reasons as to why it was not fully so. A maximum rating for comfort was given by one respondent, but the mean for the 6 subjects was only 2.67, thus indicating that the backrest was far from being fully satisfactory for this group of passengers.

Headrest

The majority (4) of the 6 respondents reported that the headrest did not give good support. It was apparently too far back for 2 of

these, and so far back for a third that he did not use it. A fourth subject said it was too flat.

The mean comfort rating for the headrest for the 5 subjects who used it was only 2.00 of a possible 4.00. None found it very comfortable, although one found it fairly so. Of the remaining 4, 3 reported it as being somewhat uncomfortable; one of these explained that the angle was not correct. A report of very uncomfortable was obtained from one respondent who gave no reason for his unfavourable rating. These data suggest that the headrest is presently incapable of providing comfortable support for passengers. However, its main function is to act as a buffer and not to provide comfort.

Seat

The mean rating for seat comfort was only 2.33. No passenger gave it the maximum rating. Although 3 apparently found it fairly comfortable, 2 of these reported that it was too shallow or short. This reason was given also by two other respondents who rated the seat as fairly and very uncomfortable, respectively. The sixth passenger gave the lowest rating without any explanation.

Clearly, the seat appears to have been uncomfortable, but this is likely because the backrest was moved out, thus shortening the seat depth. A seat that is too shallow does not allow the buttocks to move to permit changes in posture and could, therefore, generate acute discomfort. A clearance of about 5cm from the back of the knee is usually desirable. However, as the length of the femur is variable among individuals, arriving at the best seat depth measurement presents a problem. In the case at hand, ambulatory passengers should likely ride with the backrest in the upright position.

Lap and shoulder belts

Neither the lap nor shoulder belt was used by one of the 6 ambulatory passengers. Among the remaining 5, 4 used only the lap belt but gave no reason for not using the shoulder belt. Three of these responded positively regarding their feeling of support from the lap belt while the fourth made no response. The fifth subject, who used both belts, reported that he felt support from the lap belt.

All 5 subjects who used the lap belt reported feeling no discomfort from it, although one of these added that it was too binding. The subject who used both belts reported that the shoulder belt created discomfort because it was too close to the neck.

In sum, the belt system appears to have elicited from the ambulatory passengers comments similar to those obtained from wheelchair passengers, albeit fewer in number.

Armrests

The pivoting feature of the armrest was used for only one of the six ambulatory passengers, who reported that he did not consider it

essential, but that it did make getting into the seat easier. Had the sample been larger, this feature of the system might have been utilized more frequently.

The mean rating for the comfort utility of the armrests was 3.17. The subject just mentioned gave the maximum rating, reporting that the armrests contributed very much to his comfort while riding. All of the remaining 5 reported that it contributed only to some extent to their comfort. Only 2 gave comments as to how the armrests could be improved, one suggesting that more padding was needed. The other, who had suffered an arm injury, suggested lowering the armrests, thus raising the question as to the advisability of having their height adjustable.

Additional comments

Only one ambulatory respondent made an additional comment, pointing out that entry to the van is difficult because of the placement of the "extra step". Like that made by one of the driver-operators, this remark is not specifically relevant to the restraint system but underscores the utility of a holistic approach to ergonomics.

CONCLUSIONS

Problems relating to use of the system, delineated and discussed in the foregoing section, are summarized by system feature in Table 4. It is clear from this table that, despite the low return rate for the questionnaires, the study nevertheless generated a considerable amount of information regarding which design features might be adjusted in order to render the system easier to operate and more suitable for passenger use. Most of the operational difficulties can likely be resolved with minor mechanical modifications to the system. In addition, some steps could be taken to offset any negative psychological effects arising from the rather formidable appearance of the system (especially when several are installed in one vehicle). For example, providing a skylight in the van or otherwise enlarging the window space to admit light and keep the outside world in view, and fitting the system out in pleasing colours will tend to have an uplifting effect on passengers. In addition, knowledge of the very superior safety properties of the system should tend to reduce unfavourable reactions.

Table 4

SUMMARY OF POSSIBLE PROBLEMS WITH SYSTEM

System Feature	Characteristics
Arrangement in van	Limited space may create difficulty in manoeuvering wheelchairs into place. Backward-facing positions may give rise to motion sickness in some passengers. General appearance may be forbidding as view and light cut off; mechanistic properties may appear capable of damaging wheelchair.
Restraint arms	Do not accommodate electric wheelchairs. Wall-side arm difficult to release and park. Brakes of chairs get in way of hooking operation. Arm hooks tend to slip. Locking mechanism stiff.
Backrest	Cannot be used by wheelchair passengers with bags on backs of chairs. Contour may create discomfort by pressing into the back.
Headrest	Excessive movement may interfere with adjustability. May be too far back to be used by most passengers. Does not appear to have been very comfortable.
Lap belt	On wrong side of wheelchair. Pull-out lock difficult to release. Locking mechanism locks in two directions. Limited space may make fastening difficult. Appears to be too short; would not go around some chairs; tightness created discomfort for other.
Shoulder belt	Pull-out difficult to release. Tightness may create discomfort for both ambulatory and wheelchair passengers.
Armrests	Pivoting feature may not have received adequate testing. Height too low for passenger with arm injury.

Table 4
(continued)

System Feature	Characteristics
Seat	Too shallow for many. Too low for some; difficult in lowering into and rising from.

RECOMMENDATIONS FOR FUTURE TESTS

Since it is likely that further testing will be carried out after design modifications are completed, it will perhaps be worth while to present some suggestions as to appropriate methodology so as to avoid weaknesses in the present study.

A deficiency in the operability evaluation in the present case is that no provision was made for the nontechnical orientation of drivers. As a result, some guesswork had to be applied in order to interpret some of their comments. The suggested format for a future evaluation is a structured performance test in a stationary van in the presence of a trained observer who could probe for details which clearly define the nature of any operational problems. It would not be inappropriate for the observer to be the designer since his bias, being in the direction of discovering and correcting design deficiencies, would work toward, not against, the desired end.

The low return rates for the passengers in the present study suggest that their willingness to co-operate may have been over-estimated. Questionnaires received at or taken home are frequently ignored, and it is a well known fact that response rates are abysmally low in these cases. As an alternative for the future, personal interviewing is not a promising approach. Unlike the operators' tests, those for passengers are loaded with potential for psychological bias. Therefore a face-to-face interviewing technique, which is the one most susceptible to bias, is to be avoided. The recommended technique is telephone administration.

If properly conducted, such a method usually provides clean orderly data at a very high response rate the set-up should be one in which the interviewers are highly trained and supervised within a central location. Under these circumstances, missing values, so prevalent in the study at hand, are a comparative rarity because the trained interviewer is skilled at conducting pre-designed probes which tend to elicit the correct type of response to all items.

It is recommended also that a future study involve two experimental groups, one informed about the safety properties of the system, the other not so informed. Such a design would permit evaluation of the extent to which knowledge of the safety aspect of the system might off-set negative reactions to its size and mechanistic appearance. Although the informed group would undoubtably be susceptible to social desire-ability influences, these effects could be measured by responses to relevant control items.

Annex I

Forms DO, W, and A

Form DO

The new restraint and seating system you have been operating for the past while will afford your disabled passengers the same degree of safety available to those who travel by automobile. During the development of the system, a great deal of consideration was given to the task of the human operator who must get the disabled person in and out of the system. Your experience with the device would now be invaluable, before the design is finalized, in determining any modifications which could facilitate operation.

Therefore your co-operation in completing the attached sheets, seeking information on any difficulties you may be having with the system, would be very much appreciated.

NOTE:

The approach to each of the items on the attached sheets is the same. We would like you to consider a given operation, state whether or not you experienced difficulties with it, describe the nature of those difficulties and, if possible, suggest solutions.

You can help most by being very precise about the nature of any difficulty you experienced and by relating the difficulty very specifically to parts of the system.

Note that the operations are organized under the following headings in this order: Wheelchair Passengers (In), Wheelchair Passengers (Out), Ambulatory Passengers (In), Ambulatory Passengers (Out).

Your help in providing this information is much appreciated.

WHEELCHAIR PASSENGER INTO RESTRAINT SYSTEM

OPERATION	DIFFICULTIES	SUGGESTED SOLUTIONS
Back up wheelchair	Yes ___ No ___ Nature:	
Pull restraint arms forward	Yes ___ No ___ Nature:	
Place on tires	Yes ___ No ___ Nature:	
Lock	Yes ___ No ___ Nature:	
Adjust backrest	Yes ___ No ___ Nature:	
Adjust headrest	Yes ___ No ___ Nature:	
Pull lap belt across occupant	Yes ___ No ___ Nature:	
Fasten	Yes ___ No ___ Nature:	
Pull shoulder belt across occupant	Yes ___ No ___ Nature:	
Fasten	Yes ___ No ___ Nature:	

WHEELCHAIR PASSENGER OUT OF RESTRAINT SYSTEM

OPERATION	DIFFICULTIES	SUGGESTED SOLUTIONS
Release shoulder belt	Yes ___ No ___ Nature:	
Release lap belt	Yes ___ No ___ Nature:	
Release restraint arms Park arms	Yes ___ No ___ Nature: Yes ___ No ___ Nature:	
Wheel passenger out	Yes ___ No ___ Nature:	

AMBULATORY PASSENGERS INTO SEAT

OPERATION	DIFFICULTIES	SUGGESTED SOLUTIONS
Unlock armrest (when necessary)	Yes ___ No ___ Nature:	
Help passenger into seat	Yes ___ No ___ Nature:	
Lock armrest	Yes ___ No ___ Nature:	
Adjust headrest	Yes ___ No ___ Nature:	
Pull lap belt across seat occupant	Yes ___ No ___ Nature:	
Fasten	Yes ___ No ___ Nature:	
Pull shoulder belt across occupant	Yes ___ No ___ Nature:	
Fasten	Yes ___ No ___ Nature:	

AMBULATORY PASSENGERS OUT OF SEAT

OPERATION	DIFFICULTIES	SUGGESTED SOLUTIONS
Release shoulder belt	Yes ___ No ___ Nature:	
Release lap belt	Yes ___ No ___ Nature:	
Release armrest (when necessary)	Yes ___ No ___ Nature:	
Help passenger out	Yes ___ No ___ Nature:	

PLEASE RETURN COMPLETED SHEETS TO BOB MORAN

Thanks so much for your help.

The van which took you to your destination today contains newly designed wheelchair restraint equipment. Your help is needed to discover if there are any features of the system which could be altered so as to better accommodate the people who will be using it.

It is hoped that you will find it possible to complete the questionnaire. * In doing so, it would be appreciated if you would proceed in the following manner:

- Read carefully through the items without writing in your answers.
- On your next trip in the van think about the various Restraint System features the questionnaire mentions, and your reaction to those features.
- When you go home that day, write in your answers to the questionnaire items.
- However, if you feel you need more experience with the Restraint System in order to answer some of the questions, leave these until you take another trip in the van.
- When you have completed all the items PLEASE RETURN THE QUESTIONNAIRE TO THE DRIVER.

The time and thought you put into the Restraint System evaluation is very much appreciated. Thank you.

* You are of course under no obligation to do so. Moreover if, after going through the questionnaire, you find any aspect of the format or questioning objectionable, please feel free to report it to Executive Director General, Transportation Development Centre, 1000 Sherbrooke Street West, Montreal, Quebec H3A 2R3

NOTE:

Many questions are accompanied by a number of categories. For these, please just put a check mark (✓) in the category you feel best applies.

Other questions ask for open-ended comments on your category selections. In these cases, you can be most helpful by being very specific.

In all cases, your frankness will be valued, as it is only in this way that defects of the system can be recognized and removed.

1. Your age is

under 20	20 - 35	36 - 50	51 - 65	over 65

2. Are you a male? _____ or a female? _____

3. Please check which of the following disabilities apply to you

   Muscular dystrophy _____ Residual polio _____

   Spinal lesion _____ Multiple sclerosis _____

   Cerebral palsy _____ Arthritis _____

   Others _____

4. Which position did you ride in the van?
   FACING driving direction _____ or BACKING driving direction ___

5. (a) How acceptable to you was the APPEARANCE of the wheelcahir restraint?

very unacceptable	somewhat unacceptable	fairly acceptable	very acceptable

   (b) What could be done to improve its appearance?

   _____

   _____

6. (a) How SECURE did you feel while riding in the van?

very insecure	somewhat insecure	fairly secure	very secure

   (b) If you did not feel very secure, would you explain why you did not.

   _____

   _____

   (c) What could be done to the restraint system to make you feel very secure?

   _____

7. (a) How much MOVEMENT did you experience?

none	a little	a fair amount	a good deal

(b) If you did experience movement, would you indicate which one or more of the following kinds you experienced.

back and forth	_____
side to side	_____
sliding around	_____
shifting	_____
vibration	_____
up and down	_____
other (specify) _____	_____

8. (a) Did the BACKREST give you good support?

yes	no

(b) If not, please state why it did not.

_____

(c) How comfortable was the backrest?

very uncomfortable	somewhat uncomfortable	fairly comfortable	very comfortable

(d) If you did not find the backrest very comfortable, would you explain why not.

_____

9. (a) Did the HEADREST give you good support?

yes	no

(b) If not, please state why it did not.

_____

9. (c) How comfortable was the headrest?

very uncomfortable	somewhat uncomfortable	fairly comfortable	very comfortable

(d) If you did not find the headrest very comfortable, would you explain why not.

_____

10. (a) Did you feel fully supported by the LAP and SHOULDER BELT system?

yes	no

(b) If not, please explain in what way you felt unsupported by the lap belt _____

the shoulder belt _____

(c) Did you experience any discomfort from the LAP BELT?

yes	no

(d) If yes, please describe the nature of the discomfort.

_____

(e) Did you experience any discomfort from the SHOULDER BELT?

yes	no

(f) If yes, please describe the nature of the discomfort.

_____

11. Finally, would you use this section for any COMMENTS you would like to make regarding the new wheelchair restraint system, and/or for any SUGGESTIONS you have for improving it in any way whatsoever.

_____

_____

_____

REMEMBER: GIVE YOURCOMPLETED QUESTIONNAIRE TO THE DRIVER

Thanks so much for your co-operation.

Type of wheelchair?

Special accessories (if any)?

Difficulties in entering/leaving system.

Difficulties in fit or security of wheelchair and passenger.

The van which took you to your destination today contains newly designed wheelchair restraint equipment. Your help is needed to discover if there are any features of the system which could be altered so as to better accommodate the people who will be using it.

It is hoped that you will find it possible to complete the questionnaire. * In doing so, it would be appreciated if you would proceed in the following manner:

- Read carefully through the items without writing in your answers.
- On your next trip in the van think about the various Restraint System features the questionnaire mentions, and your reaction to those features.
- When you go home that day, write in your answers to the questionnaire items.
- However, if you feel you need more experience with the Restraint System in order to answer some of the questions, leave these until you take another trip in the van.
- When you have completed all the items PLEASE RETURN THE QUESTIONNAIRE TO THE DRIVER.

The time and thought you put into the Restraint System evaluation is very much appreciated. Thank you

* You are of course under no obligation to do so. Moreover if, after going through the questionnaire, you find any aspect of the format or questioning objectionable, please feel free to report it to Executive Director General, Transportation Development Centre, 1000 Sherbrooke Street West, Montreal, Quebec H3A 2R3

NOTE:

Many questions are accompanied by a number of categories. For these, please just put a check mark (✓) in the category you feel best applies.

Other questions ask for open-ended comments on your category selections. In these cases, you can be most helpful by being very specific.

In all cases, your frankness will be valued, as it is only in this way that defects of the system can be recognized and removed.

1. Your age is

under 20	20 - 35	36 - 50	51 - 65	over 65

2. Are you a male? _____ or a female? _____

3. Please check which of the following disabilities apply to you

Muscular dystrophy _____ Residual polio _____

Spinal lesion _____ Multiple sclerosis _____

Cerebral palsy _____ Arthritis _____

Others _____

4. Which position did you ride in the van?
FACING driving direction _____ or BACKING driving direction ___

5. (a) Did the BACKREST give you good support?

yes	no

(b) If not, please state why it did not.

_____

(c) How comfortable was the BACKREST?

very uncomfortable	somewhat uncomfortable	fairly comfortable	very comfortable

(d) If you did not find the BACKREST very comfortable, would you explain why not.

_____

6. (a) Did the HEADREST give you good support?

yes	no

(b) If not, please state why it did not.

_____

(c) How comfortable was the HEADREST?

very uncomfortable	somewhat uncomfortable	fairly comfortable	very comfortable

6. (d) If you did not find the HEADREST very comfortable, would you explain why not.

_____

7. (a) How comfortable was the SEAT?

very uncomfortable	somewhat uncomfortable	fairly comfortable	very comfortable

(b) If you did not find the seat very comfortable, would you explain why not.

_____

8. (a) Did you feel fully supported by the LAP and SHOULDER BELT system?

_____ yes _____ no

(b) If not, please explain in what way you felt unsupported by the LAP BELT _____

by the SHOULDER BELT _____

(c) Did you experience any discomfort from the LAP BELT?

_____ yes _____ no

(d) If yes, please describe the nature of the discomfort.

_____

(e) Did you experience any discomfort from the SHOULDER BELT?

_____ yes _____ no

(f) If yes, please describe the nature of the discomfort.

_____

9. (a) Did the driver REMOVE the ARMREST before you sat down?

_____ yes _____ no

9. (b) If yes, would you check the category below which you feel best applies to the PIVOTING feature of the ARMREST, in the case of some one with your type of disability.

- the feature is essential for safely seating the individual _____
- the feature is not essential, but it does make getting into the seat easier _____
- the feature does not help one to get into the seat _____

(c) Would you make any comments on the PIVOTING feature of the ARMREST which you feel are relevant.

_____

_____

(d) How much did the ARMRESTS contribute to the comfort of your ride?

not at all	not very much	to some extent	very much

(e) What could be done to improve the ability of the ARMRESTS to provide comfort?

_____

_____

10. Finally, would you use this section for any COMMENTS you would like to make regarding the new seat system, and/or for any SUGGESTIONS you have for improving it in any way whatsoever.

_____

_____

_____

REMEMBER: GIVE YOUR COMPLETED QUESTIONNAIRE TO THE DRIVER

Thanks so much for your co-operation.

Annex II

Code Sheets for Forms DO, W, and A

FORM DO

AMBULATORY PASSENGERS

Operation	Coded Responses
1. Unlock armrest (when necessary)	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
2. Help passenger into seat	(1) yes (2) no (9) missing value Nature - (1) seat too low (9) missing value Solutions - (9) missing value
3. Lock armrest	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
4. Adjust headrest	(1) yes (2) no (9) missing value Nature - (1) headrest too loose (9) missing value Solutions - (1) redesign headrest to eliminate excessive movement (9) missing value
5. Pull lap belt across occupant	(1) yes (2) no (9) missing value Nature - (1) too haed to release belt (2) on wrong side & hard to release (9) missing value Solutions - (9) missing value
6. Fasten	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
7. Pull shoulder belt across occupant	(1) yes (2) no (9) missing value Nature - (1) too hard to release belt (2) on wrong side & hard to release (9) missing value Solutions - (1) eliminate pull-out lock on belt (9) missing value
8. Fasten	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
9. Release shoulder belt	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value

FORM DO

AMBULATORY PASSENGERS

Operation	Coded Responses
10. Release lap belt	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
11. Release armrest (when necessary)	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
12. Help passenger out	(1) yes (2) no (9) missing value Nature - (1) seat too low causing difficulties in getting out of seat (9) missing value Solutions - (1) raise seat (9) missing value
Comments	Nature - (1) walkers do not like entering van by lift Solutions - (1) have another accessible entrance for walkers only

FORM DO

WHEELCHAIR PASSENGERS

Operation	Coded Responses
1. Back up wheelchair	(1) yes (2) no (9) missing value Nature - (1) wheelchair too wide for system (2) trouble centering wheelchair into system (3) not enough room to manoeuver (9) missing value Solutions - (1) more space between wall of van and system (2) widen restraint system (9) missing value
2. Pull restraint arms forward	(1) yes (2) no (9) missing value Nature - (1) restraint arms hard to pull out from wall (2) blocked (3) not wide enough (9) missing value Solutions - (1) widen restraint arms (9) missing value
3. Place on tires	(1) yes (2) no (9) missing value Nature - (1) restraint arms do not fit wheelchairs all sizes (2) brakes in the way (3) one plus two (9) missing value Solutions - (1) widen restraint arms (9) missing value
4. Lock	(1) yes (2) no (9) missing value Nature - (1) hard to lock down (2) lock too stiff (3) arms tend to slip (9) missing value Solutions - (1) make arm hooks rounded (9) missing value
5. Adjust backrest	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (1) backrest does not provide further comfort (9) missing value

FORM DO

WHEELCHAIR PASSENGERS

Operation	Coded Responses
6. Adjust headrest	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (1) headrest does not provide further comfort (9) missing value
7. Pull lap belt across occupant	(1) yes (2) no (9) missing value Nature - (1) hard to reach (2) wrong side of chair and hard to release (3) locks (when occupant moves) (9) missing value Solutions - (1) more working room needed (2) eliminate pull-out lock on belt (3) have locking in direction only (9) missing value
8. Fasten	(1) yes (2) no (9) missing value (1) hard to lean over (2) eliminate pull-out lock on belt (9) missing value
9. Pull shoulder belt across occupant	(1) yes (2) no (9) missing value Nature - (1) hard to release (9) missing value
10. Fasten	(1) yes (2) no (9) missing value Nature - (1) hard to release lock for seat belt (9) missing value Solutions - (9) missing value
11. Release shoulder belt	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
12. Release lap belt	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
13. Release restraint arms	(1) yes (2) no (9) missing value Nature - (1) hard to get to the one against wall of van (9) missing value Solutions - (9) missing value

FORM DO

WHEELCHAIR PASSENGERS

Operation	Coded Responses
14. Park arms	(1) yes (2) no (9) missing value Nature - (9) missing value Solutions - (9) missing value
15. Wheel passenger out	(1) yes (2) no (9) missing value Nature - (1) wheelchair gets caught on restraint arm (9) missing value Solutions - (9) missing value

(0) No difficulties

FORM W

Item	Coded Responses
1. Age	(1) under 20 (2) 20-35 (3) 36-50 (4) 51-65 (5) over 65 (9) missing value
2. Sex	(1) male (2) female (9) missing value
3. Disabilities	(1) muacular dystrophy (2) residual polio (3) spinal lesion (4) multiple sclerosis (5) cerebral palsy (6) arthritis (7) stroke (8) amputee (9) missing value (10) heart condition (11) quadraplegic (12) 3 & 5
4. Position	(1) facing driving direction (2) backing driving direction (9) missing value
5a. Appearance	(1) very unacceptable (2) somewhat unacceptable (3) fairly acceptable (4) very acceptable (9) missing value
5b. Suggested improvements	(1) the appearance looks like it could damage chair (2) system does not fit wheelchair (3) restraint's back takes up too much room in van (9) missing value
6a. Security	(1) very insecure (2) somewhat insecure (3) fairly secure (4) very secure (9) missing value
6b. Reasons	(0) NA felt very secure (1) restraint might damage wheels of chair (2) restraint does not fit chair (3) headrest too far back to provide support (4) system might tip back (5) 2 & 3 (9) missing value
6c. Suggestions	(0) NA felt very secure (1) adjustment for wheelchairs of different sizes (2) easier belt operation (9) missing value
7a. Movement	(1) none (2) a little (3) a fair amount (4) a good deal (9) missing value

FORM W

Item	Coded Responses
7b. Type	(0) NA felt no mevement (1) back and forth (2) side to side (3) sliding around (4) shifting (5) vibration (6) up and down (9) missing value
8a. Backrest	(1) yes (2) no (9) missing value
8b. Reasons	(0) NA backrest gave good support (1) too much pressure on back (2) backrest pushes into back (3) too far to give support (9) did not use, bag on chair, or missing value
8c. Comfort	(1) very uncomfortable (2) somewhat uncomfortable (3) fairly comfortable (4) very comfortable (9) missing value
8d. Reasons	(0) NA backrest very comfortable (1) backrest pushes into back (9) did not use or missing value
9a. Headrest	(1) yes (2) no (9) missing value
9b.	(0) NA headrest gave good support (1) too far back from head (2) did not use (9) missing value
9c. Comfort	(1) very uncomfortable (2) somewhat uncomfortable (3) fairly comfortable (4) very comfortable (9) did not use, or missing value
9d. Reasons	(0) NA headrest was very comfortable (1) too far back unable to reach it (9) did not use or missing value
10a. Lap & shoulder belt support	(1) yes (2) no (9) missing value
10b. Reasons	(0) NA felt fully supported by belt (1) lap belt does not go around waist (2) shoulder belt does not support upper body (9) did not use or missing value
10c. Lap belt discomfort	(1) yes (2) no (9) missing value

FORM W

Item		Coded Responses
10d.	Nature	(0) NA felt no discomfort (1) too high over arms of chair (2) too tight (9) did not use or missing value
10e.	Shoulder belt discomfort	(1) yes (2) no (9) missing value
10f.	Nature	(0) NA felt no discomfort (1) too close to neck (2) too tight (9) did not use or missing value
11.	Suggestions and comments	(1) mechanisms could be used by passenger to help in getting out (2) enjoyed the service but don't like to ride facing back of van (3) restraint system has a lot of merit especially for those handicapped who have little or no control over their limbs (4) take out seat behind driver so visibility is better (5) it seemed to serve its purpose quite well (9) missing value
12.	Type of wheelchair	(1) standard (2) electric (9) missing value
13.	Special accessories (if any)	(9) missing value
14.	Difficulties in entering/leaving system	(1) restraint hard to close on wheel (2) difficulties in positioning chair into system (9) missing value
15.	Difficulties in fit or security of wheelchair and passenger	(1) lap belt does not touch passenger, just loops over chair (2) hard to adjust seat belt (3) belt hard to reach (9) missing value

FORM A

Item	Coded Responses
1. Age	(1) under 20 (2) 20-35 (3) 36-50 (4) 51-65 (5) over 65 (9) missing value
2. Sex	(1) male (2) female (9) missing value
3. Disabilities	(1) muscular dystrophy (2) residual polio (3) spinal lesion (4) multiple sclerosis (5) cerebral palsy (6) arthritis (7) stroke (8) amputee (9) missing value (10) heart condition (11) quadraplegic (12) 3 & 5 (13) injuries (14) hemiplegic
4. Position	(1) facing driving direction (2) backing driving direction (9) missing value
5a. Backrest	(1) yes (2) no (9) missing value
5b. Reasons	(0) NA backrest gave good support (1) too close to front (9) missing value
5c. Comfort	(1) very uncomfortable (2) somewhat uncomfortable (3) fairly comfortable (4) very comfortable (9) missing value
5d. Reasons	(0) NA felt very comfortable (1) not right angle (2) not right shape (9) missing value
6a. Headrest	(1) yes (2) no (9) missing value
6b. Reasons	(0) NA headrest gave good support (1) too high (2) too flat (3) too far back (9) missing value
6c. Comfort	(1) very uncomfortable (2) somewhat uncomfortable (3) fairly comfortable (4) very comfortable (9) missing value
6d. Reasons	(0) NA headrest very comfortable (1) not right angle (9) missing value
7a. Seat comfort	(1) very uncomfortable (2) somewhat uncomfortable (3) fairly comfortable (4) very comfortable (9) missing value

FORM A

Item		Coded Responses
7b.	Reasons	(0) NA seat very comfortable (1) too shallow (short) (9) missing value
8a.	Lap & shoulder belt support	(1) yes (2) no (9) missing value
8b.	Reasons	(0) NA felt fully supported by belts (9) did not use or missing value
8c.	Lap belt discomfort	(1) yes (2) no (9) missing value
8d.	Nature	(0) no discomfort (1) too binding (9) missing value
8e.	Shoulder belt discomfort	(1) yes (2) no (9) missing value
8f.	Nature	(0) NA felt no discomfort (1) too close to neck (9) did not use, missing value
9a.	Remove armrest	(1) yes (2) no (9) missing value
9b.	Pivoting feature of armrest	(0) NA armrest not removed (1) the feature is essential for safely seating the individual (2) the feature is not essential, but it does make getting into the seat easier (3) the feature does not help one to get into the seat
9c.	Comments	(0) NA armrest not removed - no comment (9) missing value
9d.	Armrests - comfort	(1) not at all (2) not very much (3) to some extent (4) very much (9) missing value
9e.	Imprevements	(1) lower armrests (2) more padding (9) missing value
10.	Suggestions and comments	(1) find it difficult to enter van through passenger door, the extra step is not properly placed

Annex III

Raw Data

Driver-Operators

Wheelchair Passengers

Ambulatory Passengers

FORM W

ITEM \ SUBJECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	$\bar{X}$
1	3	3	3	4	4	3	5	2	2	4	1	5	2	2	4	
2	1	1	1	9	2	2	2	1	2	2	2	2	1	1	2	
3	5	4	4	7	6	8	10	3	5	2	12	4	1	11	8	
4	1	2	1	2	2	2	2	1	1	1	1	2	2	1	1	
5(a)	3	2	3	3	3	4	3	3	1	4	1	3	4	3	3	2.87
(b)	9	1	9	9	9	0	9	9	2	0	3	9	0	9	9	
6(a)	3	3	4	4	4	4	4	4	4	4	1	1	1	4	2	3.13
(b)	1	9	0	0	0	0	0	0	0	0	2	9	5	0	4	
(c)	9	9	0	0	0	0	0	0	0	0	1	9	9	0	2	
7(a)	1	1	2	1	1	1	1	2	1	1	2	1	2	1	1	
(b)	0	0	9	0	0	0	0	9	0	0	1	0	9	0	0	
8(a)	9	9	2	1	2	9	1	9	9	1	9	1	2	1	9	
(b)	9	9	1	0	2	9	0	9	9	0	9	0	3	0	9	
(c)	9	9	1	3	1	9	3	9	9	3	9	1	9	3	9	2.14
(d)	9	9	1	9	1	9	9	9	9	9	9	9	9	9	9	
9(a)	9	9	9	9	2	9	1	9	9	1	9	1	2	1	9	
(b)	9	9	9	1	1	9	0	9	9	0	9	0	1	0	9	
(c)	9	9	9	9	9	9	3	9	9	4	9	9	9	3	9	12MVs
(d)	9	9	9	9	1	9	9	9	9	0	9	9	9	9	9	
10(a)	2	2	1	1	2	1	1	1	9	1	9	1	9	9	1	
(b)	1	2	0	0	9	0	0	0	9	0	9	0	9	9	0	
(c)	2	2	2	2	1	2	9	2	9	2	9	1	9	2	2	
(d)	0	0	0	0	1	0	9	0	9	0	9	2	9	0	0	
(e)	1	9	9	9	9	9	9	9	9	2	9	1	9	1	9	
(f)	1	9	9	9	9	9	9	9	9	0	9	2	9	2	9	
11	9	9	1	9	9	9	9	9	2	3	4	9	9	5	9	
12	1	9	1	1	1	1	9	9	9	9	9	9	9	9	1	
13	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	
14	9	1	2	2	2	9	9	2	9	9	9	9	9	9	9	
15	9	1	2	9	9	3	1	9	9	9	9	9	9	9	9	

FORM A

ITEM \ SUBJECT	1	2	3	4	5	6	$\bar{X}$
1	4	4	4	5	4	5	
2	2	1	1	2	2	1	
3	13	7	4	6	1	14	
4	1	2	1	1	1	2	
5(a)	1	2	1	1	1	1	
(b)	0	1	0	0	0	0	
(c)	3	1	2	3	3	4	2.67
(d)	9	1	2	9	9	0	
6(a)	2	2	1	2	2	1	
(b)	1	2	0	3	3	0	
(c)	9	2	3	2	2	1	2.00
(d)	9	1	9	9	9	9	
7(a)	3	1	2	3	3	1	2.33
(b)	1	1	1	1	9	9	
8(a)	1	1	1	9	1	9	
(b)	0	0	0	9	0	9	
(c)	2	2	2	2	2	9	
(d)	0	1	0	0	0	9	
(e)	9	1	9	9	9	9	
(f)	9	1	9	9	9	9	
9(a)	2	2	2	2	2	1	
(b)	0	2	0	2	0	2	
(c)	0	0	0	0	0	9	
(d)	3	3	3	3	3	4	3.17
(e)	1	9	2	9	9	9	
10	9	9	9	9	9	1	

EVALUATION DATA RE TDC PROJECT NO. 8901

FORM DO

D: DIFFICULTY
N: NATURE
S: SOLUTION

OPERATION \ SUBJECT	1			2			3			4			5			6			7			8			TOTAL REPORTING PROBLEMS
	D	N	S	D	N	S	D	N	S	D	N	S	D	N	S	D	N	S	D	N	S	D	N	S	
AMBULATORY PASSENGERS																									
1. Unlock armrest if necessary	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
2. Help passenger into seat	2	0	0	1	1	9	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	1
3. Lock armrest	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
4. Adjust headrest	2	0	0	1	1	1	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	1
5. Pull lap belt across occupant	1	1	9	1	1	9	2	0	0	1	1	9	2	0	0	2	0	0	1	2	1	2	0	0	4
6. Fasten	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
7. Pull shoulder belt across occupant	1	1	9	2	0	0	2	0	0	1	1	9	2	0	0	2	0	0	1	2	1	2	0	0	3
8. Fasten	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
9. Release shoulder belt	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
10. Release lap belt	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
11. Release armrest if necessary	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	0
12. Help passenger out	2	0	0	1	1	1	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	0	0	1
Comments																			1	1					1

EVALUATION DATA RE TDC PROJECT NO. 8901

FORM DO

D: DIFFICULTY
N: NATURE
S: SOLUTION

OPERATION \ SUBJECT	1		2		3		4		5		6		7		8		TOTAL REPORTING PROBLEMS
	D	N S	D	N S	D	N S	D	N S	D	N S	D	N S	D	N S	D	N S	
WHEELCHAIR PASSENGERS																	
1. Back up wheelchair	1	1 9	1	2 1	2	0 0	1	1 9	2	0 0	2	0 0	1	3 2	2	0 0	4
2. Pull restraint arms forward	2	0 0	1	1 9	2	0 0	2	0 0	1	2 9	1	3 1	1	9 9	2	0 0	4
3. Place ontires	2	0 0	1	1 9	1	1 9	1	1 9	2	0 0	1	2 1	1	3 9	2	0 0	5
4. Lock	9	1 9	1	9 9	2	0 0	2	0 0	1	2 9	1	2 9	1	9 9	1	3 1	5
5. Adjust backrest	2	0 0	2	0 1	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	0
6. Adjust headrest	2	0 0	2	0 1	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	0
7. Pull lap belt across occupant	1	9 9	1	1 1	2	0 0	1	2 9	2	0 0	1	2 9	1	2 2	1	3 3	6
8. Fasten	1	1 9	9	9 9	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	1
9. Pull shoulder belt across occupant	1	9 9	1	1 9	2	0 0	1	1 9	2	0 0	2	0 0	1	1 9	2	0 0	4
10. Fasten	1	1 9	9	9 9	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	1
11. Release shoulder belt	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	0
12. Release lap belt	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	0
13. Release restraint arms	2	0 0	1	1 9	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	1
14. Park arms	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	0
15. Wheel passenger out	2	0 0	1	1 9	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	2	0 0	1

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